THE

GEOLOGICAL MAGAZINE

OR

Monthly Journal of Geology.

WITH WHICH IS INCORPORATED

THE GEOLOGIST.

NOS. DCLV TO DCLXVI.

EDITED BY

HENRY WOODWARD, LL.D., F.R.S., F.G.S., F.R.M.S.

LATE OF THE BRITISH MUSEUM OF NATURAL HISTORY; PRESIDENT OF THE PALÆONTOGRAPHICAL SOCIETY; ETC.

AND

R. H. RASTALL, M.A.

ASSISTED BY

PROFESSOR J. W. GREGORY, D.Sc., F.R.S., F.G.S.
F. H. HATCH, PH.D., M.INST.M.M.
PROFESSOR J. E. MARR, Sc.D. (Camb.), F.R.S., F.G.S.
SIR JETHRO TEALL, Sc.D. (Camb.), LL.D., F.R.S., V.P.G.S.
PROFESSOR W. W. WATTS, Sc.D., LL.D., M.Sc., F.R.S., F.G.S.
HENRY WOODS, M.A., F.R.S.
DR. ARTHUR SMITH WOODWARD, LL.D., F.R.S., F.L.S., F.G.S.

NEW SERIES. DECADE VI. VOL. VI.

VOL. LVI OF WHOLE SERIES.

JANUARY—DECEMBER, 1919.

LONDON:
DULAU & CO., LTD., 34–36 MARGARET STREET,
CAVENDISH SQUARE, W. 1.

1919.

STEPHEN AUSTIN AND SONS, LTD.
PRINTERS, HERTFORD

245869
JUN -7 1921
MC
.G29

LIST OF PLATES.

PLATE		FACING PAGE
I.	Dr. Charles Doolittle Walcott	1
II.	Palæolithic Flake Implements	49
III.	Pores and Channel-Systems in *Megacystis*	115
IV.	Lower Cambrian Hyolithidæ, etc., from Hartshill	157
V.	Slabs of Clay Ironstone from the Highest Coal-measures, Claxheugh, Co. Durham	211
VI.	Adoral Surfaces of *Megacystis*	262
VII.	Section across the Northern and Southern Oil- and Gas-fields of Pennsylvania	290
VIII.	*Neolenus serratus* (Rominger), Burgess Shale, C. D. Walcott	359
IX.	Fossil Myriopod from Rochdale, Lancashire	411
X.	John Hopkinson	431
XI.	*Cryptophyllum Hibernicum*, gen. et sp. nov.	441
XII.	Shell-Limestone Conglomerate at Blackhall Rocks and Jean Jiveson's Rock	498
XIII.	Rock and Spindle Shore Stack East from St. Andrews. Concentric arrangement of Ash Layers, Rock and Spindle	506
XIV.	*Bunaia Woodwardi*, gen. et sp. nov., J. M. Clarke	532
XV.	*Archæocryptolaria skeatsi*, Chapman, etc.	550

LIST OF ILLUSTRATIONS IN THE TEXT.

	PAGE
Sketch-map of Carboniferous Limestone outcrops near Wellington, Salop	78
Facial suture in Trilobites	104
Diagrammatic section of the atmosphere from the Equator to the Pole	159
Air rising in the centre of a cyclone	160
Diagrammatic section of termination of Coal-measures, S. Durham	169
Section showing position of fossiliferous ironstone bands and thrust plane	204
Section at XY in previous Figure	206
Bellinurus Trechmanni, H. Woodw., sp. nov.	210
Kyanite, Sandringham Sands	214
Zircons, Great Gransden	217
Zoned Crystals of Zircon, Great Gransden	218
Crystals of Rutile, Great Gransden	219
Map of Drake's Island, Plymouth	263
Quartz grains, Parish Sand-pit, Aspley Guise	267
Sphene, Aspley Guise	268
Kyanite Crystals, near Woburn	271
Isoseismal lines and disturbed area, Stafford Earthquake	302, 304
Earthquake cutting a crust-fold	310
Map showing site of Gravel Plain near Corwen	313
Hydropore-sutures in *Megacystis*	323
Geological sketch-map of parts of Eritrea and Abyssinia	341
Map showing the outcrops in the Harbertonford area	351
Diagram illustrating arrangements of the coarse fragments in the Crag	353
Sections at Crowdy's Quarry, New Quarry, and Copse of Austin's Close	357
Neolenus serratus (Rominger), by C. D. Walcott	360
Sketch-map of distribution of Igneous rocks, Strathbogie and Lower Banffshire	365
Iron-ore and basic steel	389
Sketch-map of part of Southern Sikkim	399
View from Badamtam across the Valley of the Ranjit	401
Map of N. India showing localities connected with Pleistocene glaciation	402

PAGE

North bank of the Great Rangit Valley 405

Five segments from the cast of *Palæosoma giganteum* 407

Reconstructed posterior segments of *Palæosoma giganteum* 408

Palæosoma robustum 409

Development of major septa in a normal Rugose Coral 436

Analysis of interambulacral tuberculation in *Pyrina* and *Conulus* . . 445

Iceland, after Th. Thoroddsen 468

Diagrammatic section across the Bryozoa Reef 486

Curve showing number of invertebrate species, Durham Permian . . 488

Diagrammatic section across the Permian outcrop 489

Diagram to illustrate structure of Rock and Spindle shore stack . . 502

Four diagrams to illustrate the occurrence, proportions, and distribution of silica in Chalk 538–44

Charles D. Walcott

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. VI.

No. I.—JANUARY, 1919.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Dr. Charles Doolittle Walcott, For. Memb. Geol. Soc. Lond., Secretary of the Smithsonian Institution, Washington (D.C.).

(WITH A PORTRAIT, PLATE I.)

DR. CHARLES DOOLITTLE WALCOTT acquired a taste for geology and natural history when very young. As a schoolboy he made large collections in the region of his home, and determined to follow a scientific career if possible.

Descended from New England settlers who emigrated from Shropshire, Dr. Walcott was born in New York Mills, Oneida County, New York (U.S.A.), March 31, 1850. His first American paternal ancestor was Captain Jonathan Walcott, of Salem, Massachusetts, who died in 1699. Of the grandfather of Dr. Walcott, Benjamin Stuart Walcott, a writer says[1] that he "moved from Rhode Island in 1822, and became one of the leading manufacturers of central New York; he had broad interests in educational matters, was the founder of a professorship at Hamilton College, and was well known as a philanthropist. His son, Charles Doolittle Walcott, was a man of unusual energy, was well established in business, and held an influential and leading place in the community. Dying at the early age of thirty-four, he left a wife and four children, the youngest, two years old, being the subject of this sketch".

Dr. Walcott's early education was in the public schools of Utica, which he entered in 1858, and in the Utica Academy, which he left in 1868. He then entered a hardware store as a clerk and, continuing in such occupation two years, acquired a practical business training, which has proved of great value to him.

His scientific tastes were developed at the age of 13, when he became interested in the systematic collecting of fossils and minerals. The following winter he met Colonel E. Jewett, geologist, palæontologist, and conchologist, from whom he borrowed books and received many suggestions. Geological reading and collecting were continued, and for two winters he devoted much time to optics and astronomy, and incidentally made large collections of insects and birds' eggs in the spring and summer months.

Of this period he says,[2] referring to fossils accidentally opened up by his wagon wheel when driving: "In a small drift block of

[1] Appleton's *Popular Science Monthly*, vol. lii, No. 4, February, 1898, p. 547.

[2] *Evidences of Primitive Life*, Smithsonian Report, 1915 (1916), p. 243.

sandstone which I found in 1867 on the road from Trenton to Trenton Falls, Oneida County, New York, there is an unusual apparent association of Upper Cambrian (Hoyt limestone) and Ordovician (Aylmer sandstone, Chazy) fossils. When as a boy I found the rounded block of sandstone referred to I broke out all the fossils possible, as at the time I was well acquainted with the Trenton limestone fauna, and the fossils in the block were strangers to me, with the exception of *Leperditia armata*. The following winter I endeavoured to locate the stratigraphic position of the associated trilobites, but could not, further than that they were evidently of pre-Trenton age. This study aroused an interest in the American early Paleozoic fossils that gradually led me to take up the Cambrian rocks and faunas as my special field of research.

"As a boy of seventeen I planned to study those older fossiliferous rocks of the North American Continent which the great English geologist Adam Sedgwick had called the Cambrian system on account of his finding them in the Cambrian district of Wales."

In 1871 business took Mr. Walcott to Indianapolis, Indiana, where his scientific tendencies were further stimulated by Professor E. T. Cox, who was then making a geological survey of the Indiana coal-fields. The time now arrived when it seemed necessary to choose between a business life and a life of research. A partnership was offered him on favourable terms, but if accepted little time would remain for study and investigation. Deciding in favour of scientific work, Mr. Walcott left Indiana and returned to New York State.

Establishing himself on the farm of William P. Rust, at Trenton Falls, he arranged to do a certain amount of farm-work for his board and lodging, reserving the remainder of his time for study and field-work. Here he remained five years, making a rich collection of unique Trenton limestone fossils, which was sold in 1873 to the Museum of Comparative Zoology of Harvard College. He made an arrangement to go to Cambridge (Massachusetts) and pursue a course of study, under the advice and direction of the great naturalist Louis Agassiz, but this was frustrated by the death of Agassiz.

Of this period Dr. Walcott writes:[1] "In September, 1873, I said to Professor Louis Agassiz that if opportunity offered I would undertake as one bit of future research work to determine the structure of the trilobite. This promise has kept me at the problem for the past forty-five years, and except for the demands of administrative duties the investigations would have advanced more rapidly. Since 1873 I have examined and studied all the trilobites that were available for evidence bearing on their structure and organization."

In November, 1876, he received his first official appointment, becoming assistant to Professor James Hall, State Geologist of New York. While holding that position researches were made in New York, Ohio, Indiana, and Canada. In July, 1879, Mr. Walcott was appointed field assistant in the United States Geological Survey, then under the direction of Clarence King, and was assigned to the

[1] "Appendages of Trilobites": Smithsonian Misc. Coll., vol. lxvii, No. 4, pls. xiv-xlii (in press).

study of the great geological section extending from the high plateaus of southern Utah to the bottom of the Grand Canyon of the Colorado. In 1882 he collaborated with Mr. Arnold Hague in the survey of the Eureka mining district in Nevada and the working out of the great Palæozoic section of central Nevada. The charge of the Palæozoic palæontology of the Survey was now assigned to him, and though this entailed considerable routine work in the identification of fossils brought from many fields by the various geologists, he was enabled to pursue with vigour his cherished plans for the investigation of the older faunas. He examined the Cambrian formations of the Appalachian belt all the way from Alabama to Quebec, and carried his researches on a more easterly line through New England and New Brunswick to Newfoundland. He also began a series of Western studies which eventually included the most important known bodies of Cambrian and pre-Cambrian rocks in Texas, Arizona, California, Idaho, Nevada, Montana, Wyoming, and South Dakota. In 1888 he was advanced to be palæontologist in charge of invertebrate palæontology in the Geological Survey; in 1891, to be chief palæontologist; and in 1893, to be geologist in charge of geology and palæontology, in which capacity he had the general direction of that branch of the work of the Survey. In July, 1894, Major J W. Powell retired from the office of director of the Survey, and Mr. Walcott was selected by President Cleveland to succeed him. This position he held until his resignation in 1907 to become Secretary of the Smithsonian Institution, of which he had previously been assistant secretary in charge of the United States National Museum. During those years he reorganized and developed the Geological Survey on scientific and business principles. The confidence reposed in him by the Congress is attested by the fact that the initial appropriation of $484,640 was increased during his administration to several times that amount ($1,700,000).

Between 1902 and 1907 Dr. Walcott directed the organization and conduct of the United States Reclamation Service. He fostered interest in the forestry movement, and in 1898 he secured the passage as an amendment to an appropriation for the Geological Survey of the first comprehensive law organizing the forest reserves of the United States.

As the initiator and secretary of the Carnegie Institution of Washington, and its direct administrative officer from 1902 to 1905, and as a member of its Executive Committee from 1902 to the present time (now chairman), he has assisted largely in the successful organization and development of the administrative and research work of that Institution.

Since 1907, when he was chosen by the Board of Regents as Secretary of the Smithsonian Institution, Dr. Walcott has directed research investigations in various parts of the world, and has personally studied large areas in the Rocky Mountains of British Columbia and Alberta, Canada. The Smithsonian foundation was established by Act of Congress in 1846, under the terms of the will of James Smithson, an Englishman, who in 1826 bequeathed his fortune to the United States of America "to found, at Washington,

under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men". It was under the direction of the Smithsonian Institution that Colonel Theodore Roosevelt (1909–10) made his memorable African expedition, being accompanied by representatives of the Institution and its branches. The administration of the Smithsonian Institution includes the Unites States National Museum, International Exchanges, Bureau of American Ethnology, National Zoological Park, Astrophysical Observatory, and International Catalogue of Scientific Literature, besides the Aerodynamical Laboratory and the National Gallery of Art.

Dr. Walcott is especially known as a student of the Lower Palæozoic (Cambrian) and pre-Palæozoic (Algonkian) sedimentary formations and included organic remains. Of his work he says[1]: "My own investigations have been mainly in the Cambrian and pre-Cambrian strata, and have involved new and somewhat startling discoveries that helped to show how very much earlier life was developed on our planet than we had previously supposed. These researches have taken into consideration the records left on all the continents and many of the great islands. Field-work, with compass, hammer, and chisel, has been the rule, followed by laboratory and critical comparison of many thousands of specimens of fossil genera and species of ancient marine life, and often study of microscopic sections of rocks and fossils in the hope of finding evidence of the presence of minute and active bacterial and simple algal workers, such as exist in modern seas and lakes, which by their united efforts form great masses of the recent sea and lake deposits."

He has worked up and correlated the Cambrian formations and included faunas on the North American continent, has personally discovered large and unique additions to the previously known Cambrian faunas, and has published his researches on the Cambrian faunas of the world; studied and developed the history and sedimentation of 30,000 feet of Algonkian sediments in western North America, and discovered and published an account of the organic remains in the Algonkian. An important find by Dr. Walcott a few years ago of a rich fossil locality in the Burgess shale, near Field, British Columbia, Canada, has given the finest and largest series of Middle Cambrian fossils yet discovered, and the finest invertebrate fossils yet found in any formation, including—besides brachiopods and trilobites — merostomes, holothurians, medusæ, annelids, brachiopods, malacostracans, etc. Many of the forms are not yet described and illustrated.

His many published works include especially studies of the Cambrian Brachiopoda and Trilobita. A few titles, suggestive of the scope of this work, are: *Paleontology of the Eureka District*, *The Cambrian Faunas of North America*, *The Fauna of the Lower Cambrian or Olenellus Zone*, *Pre-Cambrian Fossiliferous Formations*, *Correlation Papers*, *Cambrian Brachiopoda*, *The Cambrian Faunas of China*, *Discovery of Algonkian Bacteria*, *Evidences of Primitive Life*, and an

[1] *Evidences of Primitive Life*, loc. cit., pp. 235-6.

extended series under Cambrian Geology and Paleontology in Smithsonian Miscellaneous Collections, including "Appendages of Trilobites" (now in press).

Dr. Walcott's activity in other directions besides his own scientific field is well known. He is a director and was one of the founders of the Research Corporation of New York City, which is affiliated with the Smithsonian Institution. He is a member of two military committees: chairman of the Executive Committee of the National Advisory Committee for Aeronautics, appointed by President Wilson in 1915, and chairman of the Military Section of the National Research Council. Since 1917 he has been President of the National Academy of Sciences.

Of his varied inquiries Dr. Walcott says,[1] "I have had generous assistance in obtaining collections and exchanging publications with students all over the world, including geologists, paleontologists, zoologists, and paleobotanists in America and Europe, and in far-away outposts of China, Siberia, India, Australia, and New Zealand."

In 1888 he visited Wales for the purpose of making a personal study of the type district of the Cambrian system—the district rendered classic by the original labours of Sedgwick and the subsequent researches of Hicks. It was on this visit to England that he presented his Cambrian researches before the International Geological Congress at London. The London Geological Society in 1895 awarded him the Bigsby Medal, and in 1918 the Wollaston Medal.

Dr. Walcott is an active member of many scientific and literary bodies, both at home and abroad. These include the National Academy of Sciences (President), American Association for the Advancement of Science (Fellow; Vice-President, 1893), American Academy of Arts and Sciences (associate fellow), American Society of Naturalists, Geological Society of America, American Philosophical Society, Washington Academy of Sciences (President, 1899–1910), Archæological Institute of America (President, Washington Society, 1915–17), Academy of Natural Sciences of Philadelphia (Hayden Medal), Geological Society of London (Bigsby Medal, Wollaston Medal), Société géologique de France (Gaudry Medal), Christiania Scientific Society, corresponding member of l'Academie des Sciences of Institut de France, Royal Geographical Society of London, honorary member Imperial Society of Naturalists of Moscow, foreign associate Royal Academy of Sciences of the Institute of Bologna, etc.

The occasion of Dr. Walcott's visit to Cambridge, England, in 1909, was a happy one, the degree of Sc.D. being conferred upon him. Other degrees which he has received include LL.D. from Hamilton (1897), Chicago University (1901), Johns Hopkins (1902), Pennsylvania (1903), Yale (1910), St. Andrews, Scotland (1911), and Pittsburg (1912); Ph.D., Royal Fredericks, Christiania (1911), and Sc.D., Harvard (1913).

Since the entrance of the United States into the great war, in

[1] *Evidences of Primitive Life*, loc. cit., p. 236.

1917, Dr. Walcott has divided his time between war work and the administrative duties of the Smithsonian, but his leisure for research has been curtailed. In spite of this, however, he has prepared a paper of unusual interest to palæontologists, on "Appendages of Trilobites" (now in press). This represents the fulfilment of the promise to Professor Louis Agassiz, in 1873, that he would undertake the investigation of the structure of the trilobite.

To the War Service his contribution has been especially in Aeronautics. He has given two sons to the Air Service, one of whom, Benjamin Stuart Walcott, fell in combat over the German lines December 12, 1917, and the second son, Sidney, is on active service. His daughter, Helen, served for nearly a year as nurse in a French military hospital, and is now in Italy. The present war activities have made heavy claims upon Dr. Walcott's time and strength, but in spite of this he has again this summer (1918) succeeded in going on an expedition to the Canadian Rockies to continue investigations in Alberta and British Columbia.

Dr. Walcott has been favoured by fortune in many ways. A short acquaintance with him suffices to reveal some of the causes which have contributed to his success. His commanding figure is an indication of exceptional energy and physical strength, and on seeing him one is not surprised that at a ripe age he is able to carry out his field-work under arduous conditions. His unwearied industry also strikes one at once, for no opportunity for work is lost. The powers of specialization and generalization are equally developed with him; while missing no feature in the minute anatomy of some organism, he is able "to think in continents" and has thus contributed largely to the elucidation of physiographical problems connected with Palæozoic times. He can turn at will from one task to another. The onerous duties of administrative work in no wise check the enthusiasm with which he enters into his field labours. Fascinating as is the revelation of the rich faunas of the Cambrian rocks of British Columbia, he also recognizes the importance of the search for organic remains in the barren Algonkian strata, and discovers *Beltina* and "a pre-Cambrian (Algonkian) Algal flora from the Cordilleran area of Western America".

He has been fortunate in his home life. His first wife helped him with ever-ready sympathy throughout the years when he was rising to fame, and the present Mrs. Walcott is already known to the geological world by her writings. His sons and daughter have laboured with him in the field, and especially in that wonderful and prolific district of British Columbia, where so much of his recent work has been done.

Dr. Walcott has been also happy in his environment, especially of later years, when he discovered the remarkable Cambrian faunas in a region which he himself terms "a geologist's paradise". Amongst the fairest scenes of nature he has toiled month by month and year by year, and unearthed that marvellous series of faunas, one of which is preserved in a rock recalling the Solenhofen Slate alone among geological formations, so faithfully are the most delicate parts of organisms preserved in it. Truly, the Burgess shale is a silent

witness of the imperfection of the geological record, which the discovery of its treasures has lessened at a bound. We look forward eagerly to the publication of the full accounts of these Cambrian faunas, of which preliminary descriptions only have yet appeared. But Dr. Walcott has already admitted others to his paradise by the publication of the beautiful photographs and photographic panoramas of the British Columbian Alps, which bear testimony to his skill in yet another direction—as an expert photographer of mountain scenery.

Well might the ex-President of the Geological Society (Dr. Harker) state when handing the Wollaston Medal to the Attaché to the Embassy of the United States in London for transmission to Dr. Walcott, that "his personal researches have excited interest and admiration wherever geology is cultivated".

Dr. Walcott has many friends in this country who are proud of the friendship. He has been the recipient of honours here; he has encouraged British workers with much kindly help; some of his most brilliant discoveries have been made in the territories of the British Empire; and as we have seen, he has done his work and suffered loss in connexion with the great war for the sake of civilization. He has forged a prominent link in the chain that unites the English-speaking peoples on the two sides of the Atlantic.

BIBLIOGRAPHY OF CHIEF SCIENTIFIC PUBLICATIONS.

1875. "Description of the Interior Surface of the Dorsal Shell of *Ceraurus pleurexanthemus*, Green": Ann. Lyc. Nat. Hist. New York, xi, pp. 159–62, pl. xi, November, 1875. (Read June 7, 1875.)

1876. "Preliminary Notice of the Discovery of the Remains of the Natatory and Branchial Appendages of Trilobites." (Advanced print, December, 1876.) 28th Ann. Rep. New York State Mus. Nat. Hist., pp. 89–92, 1879.

1877. "Notes on some Sections of Trilobites from the Trenton Limestone." (Advanced print, September 20, 1877, pp. 3–6.) 31st Ann. Rep. New York State Mus. Nat. Hist., pp. 61–3, Albany, 1879. (Printed in pamphlet with the following, bearing date September 20, 1877.)

"Note on the Eggs of the Trilobite." (Advanced print, September 20, 1877, pp. 11–12.) Ibid., pp. 66–7, 1879.

1879. "Fossils of the Utica Slate and Metamorphoses of *Triarthrus becki*." (Advanced print, June, 1879, pp. 18–38, pls. i, ii.) Trans. Albany Inst., vol. x, pp. 18–38, pls. i, ii, Albany, 1879. (Read March 18, 1879.)

1880. "The Permian and other Paleozoic Groups of the Kanab Valley, Arizona": Amer. Journ. Sci., ser. III, xx, pp. 221–5, September, 1880.

1881. "The Trilobite: New and Old Evidence relating to its Organization": Bull. Mus. Comp. Zool. Harvard College, viii, No. 10, pp. 191–224, pls. i–vi, March, 1881.

1882. "Description of a New Genus of the Order Eurypterida from the Utica Slate"; Amer. Journ. Sci., ser. III, xxiii, pp. 213–16, March, 1882.

1883. "Pre-Carboniferous Strata in the Grand Canyon of the Colorado, Arizona": ibid., xxvi, pp. 437–42, 484, December, 1883.

"The Cambrian System in the United States and Canada": Bull. Phil. Soc. Washington, vol. vi, pp. 98–102, 1884. (Read November 24, 1883; abstract printed. Separates in December, 1883: J. B. Marcou.)

1884. *Paleontology of the Eureka District:* Mon. U.S. Geol. Surv., viii, pp. i–xiii, 1–298, pls. i–xxiv, figs. 1–6. Date on title-page 1884, but received at Survey March 16, 1885.

"On the Cambrian Faunas of North America: Preliminary Studies": Bull. U.S. Geol. Surv., No. 10, pp. 1–74, pls. i–x.

1886. "Classification of the Cambrian System of North America": Amer. Journ. Sci., ser. III, xxxii, pp. 138–57, figs. 1–9, August, 1886. (Read before National Academy of Sciences, April 23, 1886.)

"Second Contribution to the Studies of the Cambrian Faunas of North America": Bull. U.S. Geol. Surv., No. 30, pp. 1–222, pls. i–xxxiii, figs. 1–10.

1887. "Fauna of the 'Upper Taconic' of Emmons, in Washington County, New York": Amer. Journ. Sci., ser. III, xxxiv, pp. 187–99, pl. i, September, 1887.

1888. "The Taconic System of Emmons and the use of the name Taconic in Geologic Nomenclature": ibid., xxxv, pp. 229–42, March, 1888; pp. 307–27, April, 1888; pp. 394–401, May, 1888; with 13 figures and a map.

"On the Relations and Nomenclature of Formations between the Archæan and Cambrian, and the use of the term Taconic": Congr. géol. internat., Compte rendu, 4me sess., Appendix A, Reports of Amer. Comm., 1891 (1888), pp. 69.

1889. "Stratigraphic Position of the *Olenellus* Fauna in North America and Europe": Amer. Journ. Sci., ser. III, xxxvii, pp. 374–92, May, 1889; xxxviii, pp. 29–42, July, 1889.

"A Simple Method of Measuring the Thickness of Inclined Strata." (Advanced print, June 11, 1889.) Proc. U.S. Nat. Mus. for 1888, xi, pp. 447–8.

"A Fossil Lingula preserving the Cast of the Peduncle." (Advanced print, September 3, 1889.) Ibid., p. 480. (Read December 3, 1887.)

1890. "Study of a Line of Displacement in the Grand Canyon of the Colorado in Northern Arizona": Bull. Geol. Soc. America, i, pp. 49–64, February, 1890. (Read August 29, 1889.)

"The Fauna of the Lower Cambrian or *Olenellus* Zone": Tenth Annual Report U.S. Geol. Surv. for 1888–9, pt. i, pp. 509–774, pls. lxiii–xcviii.

1891. "Correlation Papers, Cambrian": Bull. U.S. Geol. Surv., No. 81, pp. 447, pls. i–iii.

"The North American Continent during Cambrian Time": 12th Ann. Rep. U.S. Geol. Surv. for 1890–1, pt. i, pp. 523–68, pls. xlii–v.

1892. "Notes on the Cambrian Rocks of Pennsylvania and Maryland, from the Susquehanna to the Potomac": Amer. Journ. Sci., ser. III, xliv, pp. 469–82, December, 1892. (Read before Philosophical Society of Washington October 29, 1892.)

1894. "Notes on the Cambrian Rocks of Pennsylvania, from the Susquehanna to the Delaware": ibid., xlvii, pp. 37–41, January, 1894.

"Paleozoic Intra-Formational Conglomerates": Bull. Geol. Soc. America, v, pp. 191–8, pls. v–vii, February 5, 1894.

"Note on some Appendages of the Trilobites": Proc. Biol. Soc. Washington, ix, pp. 89–97, pl. i, March 30, 1894.

"Pre-Cambrian Igneous Rocks of the Unkar Terrane, Grand Canyon of the Colorado, Arizona," by Charles D. Walcott; with Notes on the Petrographic Character of the Lavas, by Joseph P. Iddings: 14th Ann. Rep. U.S. Geol. Surv. for 1892–3, pt. ii, pp. 497–519 (Walcott) and 520–4 (Iddings), pls. lx–v.

"Geologic Time as indicated by the Sedimentary Rocks of North America": Proc. Amer. Assoc. Adv. Sci., 42nd Meeting, Salem, pp. 129–69; Smithsonian Inst., 48th Ann. Rep., 1893 (1894), pp. 301–34, pl. xvi.

1895. "The United States Geological Survey": Pop. Sci. Monthly, xlvi, No. 4, pp. 479–98, February, 1895.
"Algonkian Rocks of the Grand Canyon of the Colorado": Journ. Geol., iii, No. 3, pp. 312–30, pl. vi, April–May, 1895.

1899. "Pre-Cambrian Fossiliferous Formations": Bull. Geol. Soc. Amer., x, pp. 199–244, pls. xxii–viii, April, 1899. (Read December 30, 1898.)

1900. "Random, a Pre-Cambrian Upper Algonkian Terrane": ibid., xi, pp. 3–5, January, 1900.

1905. "The Cambrian Fauna of India": Proc. Washington Akad. Sci., vii, pp. 251–6, July 24, 1905.

1906. "Algonkian Formations of North-Western Montana": Bull. Geol. Soc. Amer., xcii, pp. 1–28, pls. i–xi, May, 1906.

1908. "Nomenclature of some Cambrian Cordilleran Formations." Cambrian Geology and Paleontology, i. Smithsonian Misc. Coll., vol. liii, No. 1, Publ. 1804, pp. 1–12, April 18, 1908.
"Mount Stephen Rocks and Fossils": Canadian Alpine Journ., Alpine Club of Canada, vol. i, No. 2, pp. 232–48, pls. i–iv, 3 text-pls., Calgary, Alberta, September, 1908.
"Cambrian Sections of the Cordilleran Area." Cambrian Geology and Paleontology, i. Smithsonian Misc. Coll., vol. liii, No. 5, Publ. 1812, pp. 167–230 (incl. Index), pls. xiii–xxii, December 10, 1908.

1909. "Evolution of Early Paleozoic Faunas in relation to their Environment": Journ. Geol., vol. xvii, No. 3, pp. 194–202, March–April, 1909. (Read before Section E, Amer. Assoc. Adv. Sci., Baltimore Meeting, December, 1908.)

1910. "*Olenellus* and other Genera of the Mesonacidæ." Cambrian Geology and Paleontology, i. Smithsonian Misc. Coll., vol. liii, No. 6, Publ. 1934, pp. 231–422 + Index, pls. xxiii–xliv, August 12, 1910.
"Pre-Cambrian Rocks of the Bow River Valley, Alberta, Canada." Ibid., No. 7, Publ. 1939, pp. 423–97 (incl. Index for entire vol.), pls. xlv–xlvi, August, 1910.
"Abrupt Appearance of the Cambrian Fauna on the North American Continent." Ibid., vol. lvii, No. 1, Publ. 1940, pp. 1–16, 1 map, 1 text-fig., August 18, 1910.

1911. "Middle Cambrian Merostomata." Ibid., No. 2, Publ. 2009, pp. 17–40, pls. ii–vii, April 8, 1911.
"Middle Cambrian Holothurians and Medusæ." Ibid., No. 3, Publ. 2011, pp. 41–68, pls. viii–xiii, text-figs. 2–6, June 13, 1911.
"Middle Cambrian Annelids." Ibid., No. 5, Publ. 2014, pp. 109–44, pls. xviii–xxiii, September 4, 1911.

1912. "Middle Cambrian Branchiopoda, Malacostraca, Trilobita, and Merostomata." Ibid., No. 6, Publ. 2051, pp. 145–228, pls. xxiv–xxxiv, 2 text-figs., March 13, 1912.
"Cambro-Ordovician Boundary in British Columbia, with Description of Fossils." Ibid., No. 7, Publ. 2075, pp. 229–37, pl. xxxv, March 8, 1912.
"The Sardinian Cambrian Genus *Olenopsis* in America." Ibid., No. 8, Publ. 2076, pp. 239–49, pl. xxxvi, March 8, 1912.
"Notes on Fossils from Limestone of Steeprock Lake, Ontario": App. to Memoir No. 28, Geol. Surv. Canada, (Reprint) pp. 1–6, pls. i, ii.
"New York Potsdam-Hoyt Fauna." Cambrian Geology and Paleontology. Smithsonian Misc. Coll., vol. lvii, No. 9, Publ. 2136, pp. 251–304, pls. xxxvii–xlix, September 14, 1912.
Cambrian Brachiopoda. Mon. U.S. Geol. Surv., vol. li, pt. i (text), pp. 1–872 (incl. Index), pt. ii (plates), pls. i–civ + descr. pp. 1–363 (incl. Index), text-figs. 1–76, December, 1912.

1913. "The Monarch of the Canadian Rockies: The Robson Peak District, British Columbia and Alberta, Canada": Nat. Geog. Mag., May, 1913, pp. 626–39, 12 illus. (incl. long panoramic view).

"New Lower Cambrian Subfauna." Cambrian Geology and Paleontology, ii. Smithsonian Misc. Coll., vol. lvii, No. 11, Publ. 2185, pp. 309–26, pls. l–iv, July 21, 1913.

"Cambrian Formations of the Robson Peak District, British Columbia and Alberta, Canada." Ibid., No. 12, Publ. 2186, pp. 327–43, pls. lv–lix, July 24, 1913.

"The Cambrian Faunas of China": Research in China, Carnegie Institution of Washington, vol. iii, Publ. No. 54, pp. 1–375 (incl. Index), pls. 1–29, text-figs. 1–9.

1914. "*Dikelocephalus* and other Genera of the Dikelocephalinæ." Cambrian Geology and Paleontology. Smithsonian Misc. Coll., vol. lvii, No. 13, Publ. 2187, pp. 345–498 (with Index to entire vol.), pls. lx–lxx, text-figs. 13–20, April 4, 1914.

"Pre-Cambrian Algonkian Algal Flora." Ibid., vol. lxiv, No. 2, Publ. 2271, pp. 77–156, pls. iv–xxiii, July 22, 1914.

1915. "The Cambrian and its Problems in the Cordilleran Region: Problems of American Geology": Dana Commemorative Lectures (delivered Silliman Foundation, December, 1913, Yale University), Yale Univ. Press, ch. iv, pp. 162–233, pls. i, ii, text-figs. 1–8.

"Discovery of Algonkian Bacteria" (presented to National Academy of Sciences, April 9, 1915): Proc. Nat. Acad. Sci., vol. i, pp. 256–7, text-figs. 1–3.

1916. "Cambrian Trilobites." Cambrian Geology and Paleontology, iii. Smithsonian Misc. Coll., vol. lxiv, No. 3, Publ. 2370, pp. 157–256, pls. xxiv–xxxviii, January 14, 1916.

"Relations between the Cambrian and Pre-Cambrian Formations in the Vicinity of Helena, Montana." Ibid., No. 4, Publ. 2416, pp. 259–301, pls. xxxix–xliv, text-figs. 10–13, June 24, 1916.

"Cambrian Trilobites." Ibid., No. 5, Publ. 2420, pp. 303–570 (incl. Index), pls. xlv–lxvii, September 29, 1916.

"Evidences of Primitive Life": Smithsonian Report for 1915, pp. 235–55, pls. i–xviii, Publ. 2389.

1917. "The *Albertella* Fauna in British Columbia and Montana." Cambrian Geology and Paleontology, iv. Smithsonian Misc. Coll., vol. lxvii, No. 2, Publ. 2445, pp. 9–59, pls. i–vii, May 9, 1917.

"Fauna of the Mount Whyte Formation." Ibid., No. 3, Publ. 2480, pp. 61–114, pls. viii–xiii, September 26, 1917.

1918. "Appendages of Trilobites." Ibid., No. 4, Publ. 2523, pp. , pls. xiv–xlii, 3 text-figs. (in the press).

II.—Review of Progress of Mineralogy from 1864 to 1918.

By G. T. Prior, M.A., D.Sc., F.R.S., Keeper of the Mineral Department of the British Museum (Natural History).

A BRITISH MUSEUM official may perhaps be pardoned if, in a review of the progress of mineralogy since the first appearance of the Geological Magazine, he begins with a reference to scientific work done in the Museum with which the Editor was so long associated. At the time when the Magazine first saw the light the Keeper of the Mineral Department was the late Professor Nevil Story-Maskelyne. He was one of the first to grasp that efficient tool for deciphering mineral aggregates which had been provided by Nicol and Sorby in the thin-section. He was engaged in the particular work to which Keepers of that Department have since appeared to consider they must in duty bound devote much of their time and energy, viz. the investigation of meteorites, and, assisted by the microscopic examination of thin slices of these bodies, he was

soon able to announce the discovery in them of several new species, one of which, the sulphide of calcium, oldhamite, must have been formed under conditions very different from those which prevail on the earth's surface.

Shortly before this time the sciences of both geology and mineralogy, having passed through times of stress, had been placed upon the sure foundations on which the present superstructures have been built.

In the case of geology, starting with the broad conception of the earth's crust as made up of rocks, the founders of the science, after a prolonged and bitter struggle between "neptunists" and "plutonists", had at length learned, by accepting truth from both sides, to distinguish clearly between two main types of rocks, the sedimentary, owing their origin to superficial agencies acting on the earth's surface, and the igneous, resulting from deep-seated agencies acting from the earth's interior. Guided by the principle that the present is the key to the past, which had been enunciated by Hutton and enforced by the teaching of Lyell, the geologist soon saw spread before him the ordered sequence of the sedimentary rocks, with their fossils giving a record, imperfect though it might be, of the gradual evolution of plant and animal life down the ages. Along these lines geology, on its stratigraphical and palæontological side, could develop, and has indeed continued to develop up to the present day, without feeling the necessity for paying a great amount of attention to the mineral composition of the rocks with which it dealt. The investigation of the igneous rocks, however, presented a different problem. After the main facts of the processes of vulcanism and igneous intrusion had been grasped, further progress might have been barred for a long time but for such work as that of Sorby in directing attention to the use of the microscope in determining the mineral composition of rocks. The branch of microscopical petrography thus initiated, and developed later by the exertions of Zirkel, Rosenbusch, and Teall, forms the connecting link between geology and mineralogy. As has been rightly said, mineralogy is the chief buttress on which the science of rocks, or petrology, rests; for to attempt to study rocks without minerals would be like trying to investigate and classify a group of animals by their external features with little reference to their internal anatomy.

Into an error of this kind mineralogy, indeed, had been in danger of falling in the earlier stages of its career. Under the influence of Mohs an attempt had been made to restrict the study of minerals to their natural history characters, such as crystalline form, hardness, and specific gravity, to the exclusion of the chemical properties. Mineralogy without elements would thus have been in a state comparable to that of geology without minerals. No branch of science, however, as pointed out by Sir Henry Miers in a recent lecture on this same subject before the Chemical Society, can afford to maintain a position of splendid isolation for long. Sooner or later in its development there comes a stage when for any further advance it becomes necessary to seek the aid of other sciences in order to elucidate the

new problems presented. The importance of the accurate determination of the chemical composition of minerals, as insisted upon by Berzelius and Rammelsberg, was too obvious to be long neglected; and in 1850 J. D. Dana, in the third edition of his *System of Mineralogy*, the textbook which has since become the standard work of reference for English-speaking mineralogists, rejected the natural history classification, "with its classes, orders, genera, and Latin names," as set forth in the first edition, and replaced it by a chemical one. As Dana remarked, however, the natural history classification had some advantages in "displaying many of the natural groups which chemistry was slow to recognize", for example, the felspars. A reconciliation of the purely chemical and the natural history classification was effected by Gustav Rose, who in 1852 published his crystallo-chemical system under which crystalline form was given almost as much importance as chemical composition in the distribution of minerals into groups. This was the system which was adopted by Story-Maskelyne for the re-arrangement of the mineral collection of the British Museum. The general acceptance of such a system, in which minerals were classified, in the first place by chemical composition, and in the second place by crystallographic characters so as to bring together members of isomorphous groups, marked a distinct advance in the science of mineralogy.

It was in the very year in which the Geological Magazine first appeared that Tschermak published his discovery of the nature of the felspar group. The fact that minerals with such apparently dissimilar chemical compositions as albite and anorthite should crystallize together in all proportions threw a new light upon the principle of isomorphism, and helped to pave the way towards the modern view that it is the arrangement in space of the atoms themselves that determines the crystal structure.

During the period under review, indeed, the great problem which has exercised the minds of mineralogists has been the determination of the connexion between the chemical composition, the crystalline form, and the physical (more especially optical) characters of minerals.

The close interrelation between optical and crystallographic characters had been to a large extent already recognized by the work of Brewster, who had shown how different types of crystals differed in their behaviour towards polarized light. The gradual accumulation of knowledge which led to the distribution of crystals into groups or systems, each distinguished from the others by the optical characters of its members, is well brought out in the *Introduction to the Study of Minerals*, one of the British Museum Guidebooks, first published in 1884, for which geologists desirous of gaining some knowledge of minerals owed a debt of gratitude to Sir Lazarus Fletcher, the successor to Story-Maskelyne in the Keepership of the Mineral Department. The exact determination of the optical characters of rock-forming minerals such as the felspars, pyroxenes, and amphiboles, which has been rendered possible, first by the researches of Des Cloizeaux and Tschermak, and later by the improvements in apparatus and methods effected by more modern

workers, of whom mention may be made of Becke, Fedorov, and Wright, is of the utmost importance for the development of petrology. Such advances have been made in this direction that it will soon be possible from the determination of the optical characters of any one of these minerals, as seen in thin-sections under the microscope, to make fairly accurate deductions as to its other properties, including the chemical composition.

Steps towards the solution of the other branch of the problem with which mineralogists have been concerned, viz. the connexion between crystalline structure and chemical composition, had also been taken, before the period under review, in the study of isomorphous groups. More recently, series of brilliant researches, of which those made by Tutton on isomorphous groups of sulphates and selenates are the most remarkable, have shown that the individual members of such groups are not crystallographically absolutely similar, but that quite definite and concordant, though minute, changes in the crystal form and optical characters are produced by the replacement of one metal by another. Most notable also in this connexion are Penfield's classic demonstration of the isomorphous replacement of fluorine and hydroxyl, and his investigation of the morphotropic relations of the members of the humite group of minerals.

It was as far back as 1850, however, that perhaps the most striking advance was made towards the goal to which mineralogists were striving. In that year was published what might appear at first sight to have little bearing upon the matter, viz. the mathematical memoir of Bravais on the regular arrangement of points in space. Bravais' work was a more complete development of the geometrical investigations of Frankenheim on parallelepiped networks of points known as space-lattices. In a space-lattice points are arranged in space for the most part at the intersections of three sets of planes, the planes in each set being parallel and spaced at equal distances apart. In such an arrangement space is divided up by the points into parallelepiped cells, just as the space of a room may be regarded as divided up into so many cubic inches, the shape of the cell depending upon the inclinations to each other of the three sets of planes, and upon the distances apart of the parallel planes in the three sets. It was assumed that as crystals are homogeneous structures they must be built up of units occupying the position of points in space-lattices; and according to the particular kind of space-lattice, i.e. to the shape of its elementary parallelepiped cell, crystals could be divided into the same seven systems into which they had been grouped by the consideration of crystal-symmetry.

Since the publication of Bravais' memoir crystallographers have realized that crystals can be divided according to the degree of symmetry they exhibit, i.e. according to the number of planes and axes of symmetry they possess, into thirty-two distinct classes, and that these may be regarded as to some extent mutually independent, although capable of being distributed through the seven larger systems according as they have certain geometrical and physical relations in common. The fact that only thirty-two types of symmetry are possible in crystals had been discovered by Hessel as

far back as 1830, and rediscovered by Gadolin in 1867, but the actual grouping of crystals into these classes is of comparatively recent date; for although prominence is given to it in Miers' *Mineralogy*, published in 1902, and in Lewis, *Crystallography*, published in 1899, it is not taken into account in Story-Maskelyne's *Morphology of Crystals*, published in 1895.

Now space-lattices only sufficed to represent the symmetry of the most symmetrical (holohedral) class in each system. It has been the work first of Sohnke and later of Schönflies, Fedorov, and Barlow to show how all the thirty-two types of symmetry recognized in crystals can be represented by point-systems, which are generally reducible to a certain number of interpenetrating space-lattices in each case of the same kind. The kind of space-lattice determines the system, but the mode of interpenetration of several lattices of the same kind determines the particular class in that system. In setting up a crystal, crystallographers have now in most cases to choose as axial planes three faces which they have reason to suppose are parallel to three sides meeting in a corner of the elementary cell of the space-lattice. Recently Fedorov, by choosing crystallographic axes somewhat on these lines, has prepared a general table of the characteristic angles of all measured crystals, which makes it possible to identify quickly from its crystals any substance that has been previously measured.

The question now arose as to the nature of the units involved in the crystal structure. The old notion that the crystal-molecule consisted of a polymerization of many chemical molecules was soon discarded, and, through such a work as that of Tutton, the idea was gaining ground that the units in the crystal structure might be single molecules or even the atoms themselves, when Barlow and Pope brought forward their well-known valency theory, according to which the crystal structure of any chemical compound can be explained by the "close-packing" of spheres representing the atoms of its molecules, the sizes of the spheres being approximately proportional to the valencies. This theory has been applied with a fair measure of success to many organic compounds as well as minerals, though the recent demonstration, by means of X-ray experiments, of the equality in volume of the elementary cells of the space-lattices of crystals of ammonium sulphate and rubidium sulphate, would appear to suggest that some modification of it may be necessary which shall take into account other properties of the atom besides the valency.

Quite recently, as all the world knows, actual experimental proof has been forthcoming of the space-lattice arrangement in crystals. To Laue first came the truly brilliant inspiration that, just as a closely ruled (1,000 lines to the inch) diffraction grating behaves towards light with its wave-lengths measured in thousandths of a millimetre, so it was conceivable would the parallel planes of atoms, as arranged in interpenetrating space-lattices in a crystal, behave as diffraction gratings to X-rays with their wave-lengths (of the order 10^{-9} cm.) so infinitely more minute than those of light. The experimental testing of this stupendous idea was marvellously

successful. Photographic plates exposed to X-rays which had traversed plates of crystals showed spots of maximum effect which were distributed in accordance with the symmetry of the crystal. In the hands of W. H. Bragg and W. L. Bragg a modification of this method of experiment has given results, the most reasonable interpretation of which fixes the actual arrangement in space of the atoms in crystals of many minerals. In crystals of common salt, for example, the experimental data indicate that the atoms of sodium and chlorine are each distributed on a separate space-lattice of which the elementary cell is a centre-faced cube (i.e. a cube with points not only at the corners but also at the centres of faces), the two lattices interpenetrating in such a way that the sodium and chlorine atoms occur alternately at equal distances apart. In another cubic mineral, iron pyrites, the three atoms of its molecule are again distributed on centre-faced cube lattices, but the interpenetration of the three lattices is so much more complex as to account for the fact that whereas salt crystallizes in the most symmetrical holohedral class, iron pyrites belongs to the less symmetrical pyritohedral class.

With the account of this brilliant consummation this review may well come to a close. Limits of space allow of a reference only to the wonderful series of experiments by van't Hoff and his pupils on the Stassfurt salt deposits, which have shown how their minerals separated from solution; and to the investigations by Vogt, Doelter, and the band of energetic workers in the Geophysical Laboratory at Washington on the problem of the crystallization of silicates and sulphides from fused magmas. These researches which are still in progress are of great geological interest, as they may be expected to throw much light upon the origin of rocks and ore deposits. Other recent investigations, also having their appeal to geologists, are the determinations by Fenner of the temperatures of inversion of quartz, tridymite, and cristobalite, which enable these silica-minerals to be used as geological thermometers; and the use made by Joly, Strutt, and others of radioactive work on the rate of disintegration of unstable elements such as uranium and thorium in order to measure geological time, and thus to help towards the solution of the vexed question of the age of the earth. Many of these researches, however, as well as the attempts, both experimental and theoretical, made by Clarke, Tschermak, and others, to elucidate the chemical constitution of silicates, have been the subject of some controversy; and none have as yet reached such a climax as the demonstration of the atomic structure of crystals.

This last attainment, it may be noted, has been the result of a gradual extension of investigation from great things to the infinitely small. The science of geology began with the study of rocks, the large bodies which constitute the earth's crust. In order to determine the composition of rocks geology had to seek the aid of mineralogy. The latter science, in its turn, after concerning itself at first mainly with the natural history characters of minerals, had to apply for knowledge of their elemental composition to the science of chemistry which it had itself originally created. Finally physics and mathematics had to be invoked in order to explain how the

atoms of the elements are arranged in space in order to produce those exquisite shapes, the crystals, in which minerals generally occur. It may be that the problem of crystal structure will eventually receive its complete solution by a continuation of the same process in making use of the knowledge now being acquired of the complexity of the atom and the immense forces stored up in it. Mineralogists, having done so much for crystals, may then perhaps direct more attention to the study of non-crystalline colloidal minerals, and thus possibly forge a connecting link with the biological sciences.

In conclusion, the dominant impression produced by a review of the progress of mineralogy during the past half-century is that it is only in their initial stages that natural history sciences can attempt to keep in rigid compartments mutually independent of each other. As they continue to advance the greater becomes the necessity, and this is true not only of those which concern themselves with the inorganic world but also of those which deal with the living things upon it, to stretch out for aid to the sciences which really stand at the base of all others—chemistry, physics, and mathematics. In the future it is probable that a much more thorough training in these fundamental sciences than is at present considered sufficient will be regarded as an essential preliminary to the proper study of any department of natural history.

III.—A Mines Department for the United Kingdom.

THE formation of a new Government organization to foster and promote the interests of the Mining Industry of the United Kingdom has been recently proposed in two distinct quarters. The Coal Conservation Committee of the Ministry of Reconstruction, which issued its report (Cd. 9084) early in the past year, recommended the establishment of a Ministry of Mines and Minerals, to be presided over by a Minister with a seat in Parliament; while in a report to the Minister of Munitions, issued as a white paper (Cd. 1984) on November 15, Sir Lionel Phillips, late Controller of the Department for the development of Mineral Resources in the United Kingdom, favours the setting up of a Mines Department, to be attached to one of the existing great Departments of State.

In a country like ours, which has probably greater mineral wealth than any area of equal size on the globe, and where the development of vast untapped resources of coal and iron-ore is to some extent hampered by ancient vested interests, the necessity for an organization of the kind indicated scarcely needs any advocacy. We can therefore confine ourselves to the discussion of the functions that such a Mining Department should be designed to fill.

Some of them are already performed by various existing Government departments. Thus the *Home Office* administers the legislation affecting mines and quarries and, in connexion therewith, carries out an inspection by qualified officers: it also collects and publishes in an annual report certain statistics regarding accidents, labour, and output; and it conducts examinations for colliery managers' certificates. The *Board of Trade* collects, under the Census

of Production Act, 1906, particulars of the quantity and value of the output of coal, metalliferous minerals, and of works engaged in the smelting of metals; and during the War it has been largely concerned with the regulation of the supply and distribution of coal and coke. The *Board of Education*, in its capacity as administrative head of the Geological Survey (in succession to the old Science and Art Department), has to do with the Geological Survey of the United Kingdom, i.e. with the preparation of geological maps, explanatory memoirs, and of special Reports on Mineral Resources, as well as the maintenance of a Museum of geological collections and economic resources. The *Woods, Forests, and Land Revenues*, through its Commissioner, acts as Gaveller of the Forest of Dean and also exercises the rights of the Crown in respect of mines under the sea, below high-water mark, in all parts of the Kingdom. Similar Crown rights are exercised by the *Duchies of Lancashire and Cornwall*. During the War the *Ministry of Munitions* has, under the Defence of the Realms Act, exercised many of the functions of a Mines Department. Its activities with regard to minerals have separated naturally on the lines of ferrous and non-ferrous. Through its Iron and Steel Department under the administration of Sir John Hunter and Colonel Charles Wright, C.B., it has been able to develop rapidly home supplies of iron-ore so as to more than make up for any loss of foreign supplies due to the activities of the enemy submarines; in connexion with this, it became necessary, in order to properly gauge the industrial situation, to organize the collection of very complete statistics of production of raw and semi-finished materials, and it is understood that in the course of this work a most valuable series of records has been accumulated. The Department for the Development of Mineral Resources was established for the purpose of increasing in the United Kingdom the supply for War purposes of minerals other than coal and iron. Sir Lionel Phillips was made Controller; and his Report, which has just been issued, is the one referred to above.

The proposal made by the Coal Conservation Committee is that the duties hitherto performed by so many different Government bodies should, with certain specified exceptions, be transferred to and administered by a Ministry of Mines for the United Kingdom. The functions of such a Ministry would from the foregoing appear to be: to collect statistics of production, consumption, and metal requirements of the United Kingdom; to provide for the certification of the managers of all mines and quarries; to safeguard the health and safety of the employees by administering the legislation affecting mines and quarries; and finally, to set up machinery to deal with such local mining problems as the working of barriers, the drainage of waterlogged areas, wayleaves, royalties, etc.

In Sir Lionel Phillips' scheme it is suggested that there should be attached to the proposed Mines Department, (1) an Imperial Mineral Resources Bureau, forming a link with the self-governing Dominions, (2) a Mines and Minerals Commission to watch and foster the interests of the Empire in the output and trade in mineral and metallic products. Other notable points in his scheme are (1) the

appointment of commissioners authorized to take action in cases of improper exploitation of properties, or unreasonable or prohibitive conditions imposed by landowners for royalties and wayleaves; (2) the provision and administration of a fund for the purpose of undertaking experimental work.

Since Sir Lionel Phillips wrote his report an Imperial Mineral Resources Bureau has been set up. It has been designed as an Imperial link between the respective Mines and Mineral Departments of the self-governing Dominions, India, and the United Kingdom, and its constitution would not appear to permit of its being attached to a Mines Department of the United Kingdom. The Bureau is, we understand, already at work on its internal organization. It is an Imperial body to be incorporated by Royal Charter under the Presidency of the Lord President of the Council, with a governing body containing representatives appointed by the self-governing Dominions, India, and the United Kingdom, as well as certain technical men appointed by the Minister of Reconstruction to represent the mineral, mining, and metal industries generally. In the collection of statistical information it will work through the Mines Departments of all parts of the Empire, including the United Kingdom, and as an Imperially constituted body its relations to a Home Mines Department should be of similar nature to those of the self-governing Dominions.

From what has been said, however, it must be clear that it would be a great advantage for the dispatch of important business relating to the mining industry of this country to bring under one official head the functions performed by so many different governing bodies. Whether an independent Ministry should be formed or to what existing Department of State a Mines Department should be attached are questions of comparatively minor importance. But if a Ministry to deal with Commerce and Industry were to be formed this would obviously be the proper home for a Department of Mines and Minerals, just as in France the *Conseil général des Mines* is a department of the *Ministre des travaux publics.*

IV.—The Interior of the Earth.

By R. D. Oldham, F.R.S., F.G.S.

Being the Introduction to a Geophysical Discussion organized by a Committee of the British Association for the Advancement of Science, and held in the rooms of the Royal Astronomical Society on November 19, 1918.

WHEN I received the invitation to open this discussion my first feeling was of diffidence, for, the interior of the earth being necessarily inaccessible to direct observation, the solution of the problems connected with it has principally been left to mathematical research, and this must remain the final court of appeal. In these circumstances it seemed verging on presumptuousness to address an audience consisting so largely of mathematicians in inauguration of a discussion on the interior of the earth. Second thoughts showed

that there was much to be said against this view, for, though mathematics is the court of appeal, it can only decide on the facts placed before it by the sciences of observation, and so the discussion seems profitably prefaced by a statement of the leading facts which have been collected, and those conclusions which are so directly derived from them as to have almost the validity of observation.

The first, and still one of the most important, of these observations is that the temperature rises regularly to the greatest depth yet penetrated into the earth, the rate of increase being on the average about 1° C. for every 25 m. of depth; we also know that at depths from which volcanic eruptions take place the temperature reaches at least 1000° C. So long as the nebular hypothesis held undisputed sway, it was natural to suppose that the increase of temperature was continuous to the centre of the earth, and, as long ago as 1793,[1] we find Benjamin Franklin indicating the necessary corollary from this, that below a certain depth the material, of which the earth is composed, must necessarily be in a molten, and, at a still greater depth, be converted into a gaseous, condition, an hypothesis very similar to that associated in recent times with the name of Arrhenius.

The fundamental assumption on which this deduction is based has been sapped by the discovery that the radium content of the outer layers of the earth is amply sufficient to account for the whole of the temperature gradient observed in its superficial portion, and, other considerations being ignored, the hypothesis which has been seriously proposed, that the innermost parts of the earth may be intensely cold, approaching the absolute zero temperature of space, is a possible one. We have also the demonstration that the earth as a whole is something like twice as rigid as an equal-sized globe of solid granite, which precludes the assumption that the interior can be in a fluid or gaseous condition in any ordinary sense of the word, but here we must allow for the effect of pressure. When it is remembered that at a depth of but 4 km., or about 2½ miles, the pressure is already greater than the crushing strength of the strongest known rock, and that at the centre it is about three thousand times as great as this, it becomes evident that the properties of matter may be very greatly modified and that the terms used to describe the three states, as we know them under surface conditions, may need to be used in a very esoteric sense when transferred to the interior of the earth. For the present all that need be said is that material, which can be shown to be from twice to six times as rigid as strong granite, can only be described as fluid or gas in a very Pickwickian sense of the word, and it is possibly a mere accident that the threefold division of the interior, outlined by Benjamin Franklin, comes so near that which I propose to show is the deduction to be drawn from the present state of knowledge.

Taking the outer layers of the earth first, we find that the rocks which are exposed at the surface consist in part of material which has been disintegrated by the processes of surface denudation, transported, deposited, and resolidified, and partly of rock which has not

[1] Trans. Amer. Phil. Soc., iii, pp. 1-5, 1793.

yet undergone these processes, but is thoroughly cooled and solid in every sense of the word. To the greatest depth yet reached the rocks are of this type, and it evidently continues for some distance below the depths which can be reached by direct observation or by immediate deduction. This outermost portion of the earth, in which the physical condition is similar to that of the surface rocks, is commonly known in geology as the crust, a name which originated in the days when the earth was supposed to consist of a molten interior and an outer solid crust, and has survived that supposition for want of a better, and after all the word does not necessitate a fluid interior; a loaf of bread, for instance, has a crust, though the interior should be solid. At the present day the term means no more than the outer layers in which composition and constitution have not undergone any great change, as opposed to the more deeply seated material, which differs on one or both of these characteristics. The thickness of this outer crust has been estimated by various methods, the increase of temperature, the pressure under which certain minerals must have been formed, the strength of the crust as indicated by the anomalies of gravity, and some others, all of which agree in putting the lower limit at about 50 km., or some 30 miles, well under one-hundredth of the radius of the earth.

In the outer regions of the crust geological investigation has shown that movements of displacement have taken place on a large scale. Over widths of some hundreds of kilometres rocks have been compressed to the extent of one-third to one-half or less of their original extension, as is shown by the folds into which originally horizontal strata have been thrown. In other cases clean-cut, gently sloping, or horizontal fractures have been recognized, and, along these fractures, displacements have taken place to the extent, well established, of over 60 km. and in some cases possibly of over double this, or from $\frac{1}{2}^\circ$ to 1° of the circumference of the earth. In other places there is evidence of extension, much less capable of measurement than the compression, which, though probably smaller on the whole than the compression, may be comparable in amount. Displacements in a vertical direction have also been well determined, along defined surfaces of fracture the displacement of opposite sides of faults has been established up to about 5 km., and possibly to half as much again, and, as regards places less than a couple of degrees apart, such as the crests of the Himalayas or Andes compared with the plains at their foot, or the mountains of Japan with the bottom of the Tuscarora deep, the vertical displacements may be as much as 15 km.

The cause of these great earth-movements is still an unsolved problem of geophysics. At one time they were generally attributed to compression of the earth's crust through contraction due to gradual cooling, and the notion is by no means extinct, but the curiously local distribution of the compression is against this interpretation, no less than the fact that the amount is largely in excess of any contraction permissible on this hypothesis, and besides we have the equally well-established facts that regions of very considerable extent show signs of tension and expansion of their dimensions.

Especially in the case of the great thrust-faults is explanation difficult; the appearances are such as suggest a simple fracture and displacement by compression due to approach to each other of the limits of the region affected, but it can easily be shown that the thrusts involved in this explanation are many times greater than those which could be transmitted by the material of which the blocks are composed. The final explanation must wait until it can be treated by one who is at the same time fully cognisant of the geological results and of the physical principles involved, probably also till a further advance is made in our knowledge of the physical properties of the material under conditions such as exist, even at the comparatively small depths involved.

Leaving this question aside, it is clear that extensive displacements have taken place in the outermost layers of the crust, and these are presumably taken up, possibly in a somewhat different form, by the lower layers, but in any case necessitate that, below the rigid and solid crust, must come material which possesses some of the properties attributed to a fluid, though not necessarily more than the power of changing its form when exposed to stresses of sufficient magnitude and of long enough duration. This has been recognized for some time, and we were content to accept the general conclusion without giving it a name, but this does not satisfy American thought, and Professor J. Barrell has not only introduced the name asthenosphere for the region of material comparatively weak as against permanent stress, but has given a numerical estimate of this weakness or strength. According to him the material at the weakest part of the asthenosphere reached by his investigation, placed at 400 km. from the surface, is about $\frac{1}{25}$ of that of massive surface rocks, and of the order of a capacity of sustaining stress differences of about 1,000 lb. per sq. in. with extreme permissible limits of 100 and 5,000 lb. per sq. in. At this depth the conclusions drawn from his method of deduction become distinctly doubtful, but, at the lesser depth of 50 km., the strength is only about six times that quoted and at 100 km. about four times this amount.[1]

The nature of the transition from the solid crust, or lithosphere, to the underlying asthenosphere is of interest, and on it two lines of reasoning can be brought to bear. First, we have Professor Barrell's calculations, according to which the permanent strength between the depths of 20 and 30 km. amounts to about four to five times that of granite, and at a depth of 50 km. to only one-quarter, showing a very rapid diminution of strength at depths below 30 km. and a tolerably abrupt transition from the crust to the underlying material. The other line of reasoning depends on the phenomenon of reflection of earthquake waves. It is now pretty well established that long distance records, when clear enough, show the arrival not only of waves which have travelled from the origin by a direct path, but of others which have been reflected at or near the surface. In the mathematical treatment of these waves it is necessary to assume

[1] *Journal of Geology*, xxiii, p. 44, 1915.

a spherical body with a definite outer surface, from which reflection takes place, and it was not unnatural to regard this as the outer surface of the earth, but there are some very real difficulties in the way of this interpretation. Just thirty years ago Dr. C. G. Knott showed[1] that, in the heterogeneous material of which the outer layers of the earth are composed, simple condensational and distortional waves could not be transmitted, as each would undergo a breaking up into two forms at every passage from rock of one kind to that of another; ten years later Professor M. P. Rudzki further showed[2] that only a very small proportion of known rocks possessed those characters of elasticity which would enable them to transmit unaltered the two simple forms of elastic waves, and the records of seismographs show that the movement of the wave particle at the surface is of a very complicated nature, having no relation to the simple movements required by the theory of reflection. For these reasons it seems probable that the reflection, of which we find evidence in long distance records, does not take place at, but a short distance below, the surface, and it is natural to place it at the limit where the more heterogeneous rocks of the outer layer pass into the more homogeneous material of the central core—in other words, at the lower limits of the crust or at about 30 km. below the outer surface. Professor Barrell's figures suggest that the limit is probably sufficiently defined to give rise to reflection, and the fact that the reflected waves are not always equally conspicuous is in consonance with the natural assumption that the lower limit of the crust may be more sharply defined in some places than in others, an assumption which is strengthened by fact that these reflected waves are especially conspicuous where the point of reflection lies under the great nexus of mountains forming the Pamir Plateau and the "Roof of the World". It is not unnatural to suppose that this region, unique as regards surface features, should be equally singular in the character of the under surface of the crust, and so give rise to the more than usual prominence of the reflected waves, where incidence takes place under this region.

For the rest of the interior of the earth we are principally dependent on the results obtained by the modern development of seismology. When it was recognized that the long distance records of great earthquakes represented the arrival of mass waves which had travelled through the earth it must have occurred to more than one worker that they would give information regarding the constitution of the material traversed by the wave paths, but I know of no published work previous to a paper by myself, read before the Geological Society in February, 1906, on the "Constitution of the Interior of the Earth as revealed by Earthquakes",[3] to which, doubtless, I owe the honour of having been invited to address you to-day, and in treating the subject the most convenient course

[1] Trans. Seismol. Soc. Japan, xii, pp. 115 ff., 1888.
[2] Beiträge z. Geophysik., iii, pp. 519-40, 1898.
[3] Quart. Journ. Geol. Soc., lxii, p. 456, 1906.

will be to outline the position as there presented, and the modifications which have been introduced by subsequent work. In 1905 there were twelve earthquakes of which direct and accurate knowledge was available of the place and time of origin, and two of which the place was known, but the time had to be inferred from distant records. Tabulating the records of these earthquakes, it was found that the intervals taken by the first and second phases to reach the place of record increased regularly up to a distance of about 120° from the origin. The rate of transit increased more rapidly at first, less rapidly later, and showed that the deeper the wave path penetrated the greater became the rate of transmission, which meant that the wave paths were curved with a convexity towards the centre of the earth. Up to 120° there was no breach in the regularity of the time curve, and the ratio between the rate of propagation of the condensational and distortional waves remained much the same; beyond 120° distance an irregularity appeared, the first phase, or commencement, was appreciably delayed, and the second phase completely disappeared, only at about 140° did something reappear which was recorded as second phase, but must either be distinct from the second phase at lesser distances, or be delayed by about ten minutes in its arrival. From these facts it was concluded that the earth, down to the depth reached by wave paths emerging at 120°, or to a little more than half the radius measured from the surface, was composed of material capable of transmitting the two primary forms of wave motion, and that down to this depth there was no indication of any change of condition, the increase in elasticity, indicated by the increasing rate of propagation, being no more than might be attributed to the increased pressure and compression of the material. Beyond this depth there is a rapid transition to a material which can only transmit the condensational waves at a somewhat reduced rate, and is either incapable of transmitting the distortional waves, or transmits them with a reduction to about half the velocity attained in the lower parts of the outer shell; at that time it was impossible to decide between the two alternatives which were both presented, with some leaning towards the former.

In dealing with subsequent developments it will be convenient to take the two parts of the time curve, and of the resulting parts of the earth's interior separately. Beginning with the outer shell the first work to be noticed is the often quoted paper by Professor Wiechert, which appeared in 1907,[1] where the subject is treated in a more elaborately mathematical form, and appended to it is a detailed discussion of the records by K. Zöppritz, the most important part of which, from the present point of view, is the discussion of the depth reached by the wave paths. For those emerging up to a distance of about 45° the depth reached by the two wave paths is about the same, and increases rapidly at first, then less rapidly; from 45° to about 70°, where the depth reached is about 1,400 to 1,500 km., there is very little increase, but a considerable difference

[1] "Ueber Erdbebenwellen": Göttingen Nachrichten, 1907.

in the depth reached by the two forms of waves; beyond that distance the depth reached increases again, and gradually becomes more equal for the two forms of wave motion till the limit of about 120° is reached. In detail these results have been modified by later work and more exact and numerous determinations of the time intervals, which Professor H. H. Turner has, within the last three years, found to require considerable corrections; it is also a fact that the mathematical methods were not altogether sound, and quite recently the problem has been tackled anew by Dr. C. G. Knott.[1] He informs me that he has succeeded in solving the integrals in an unequivocal manner, no longer needing the use of any assumptions, as had previously been used by himself and by Professor Wiechert. From this he has computed and plotted the wave paths for various distances, which show that those emerging at from 45° to about 75° are crowded together in their deepest-lying parts, in a zone lying just outside about one-quarter of the radius from the surface, or at a depth of 1,300 to 1,500 km. The flattening of the wave paths in this region shows that the increase in rate of propagation suffers a check, and in the case of waves emerging at 73° the lower part of the path is actually concave towards the centre, indicating a temporary decrease in the rate of travel.[2]

The coincidence of these results make it apparent that a change of some kind takes place in the neighbourhood of 1,400 km., or rather less than a quarter of the radius, from the surface, but it is equally clear that it is not a change of state, for both here and at greater depths the two forms of simple mass waves continue to be propagated at about the same relative rates as is demanded by theory. The change indicated is rather of chemical composition than of physical constitution, and in discussing this it is necessary to hark back.

There is a considerable body of evidence, principally astronomical, though partly also geological, which goes to show that the central portion of the earth is composed of metal, principally iron, surrounded by a sheath of stony material. In part this deduction is reached from spectroscopic analysis of the sun and stars, in part from the composition of meteorites, which, whether regarded as the fragments of older worlds, or as the material from which worlds are built up, may be regarded as fair samples of the composition of our earth, and in part from certain geological observations which indicate that deep down in the earth masses of metallic iron are associated with the

[1] Not yet published in full; for an abstract see *Nature*, November 21, 1918, p. 239.

[2] In this connexion it is noteworthy that just a year ago Dr. G. W. Walker announced his conclusion that many of the earthquakes which give rise to long distance records originate at about this depth (Brit. Assoc. Rep., 1917). The conclusion cannot be regarded as fully established, and there are some difficulties in the way of its acceptance, but it is an important and interesting suggestion, which must receive serious consideration, with the reservation that the origin is not of the earthquake proper but of the bathyseism, of which the surface quake, which is felt and does damage, is a secondary result (see Quart. Journ. Geol. Soc., lxv, p. 14, 1909).

stony matter of the outer layers. This hypothesis was mathematically investigated by Professor S. Wiechert in 1897,[1] who found that, within permissible variations, the earth might be regarded as composed of a central core of density about 8 and an outer sheath of density about 3, the dimension of the core being from about three-quarters to less than four-fifths of the radius of the earth, according to the actual densities adopted, and that such an earth would satisfy the known conditions of mean density, as well as of precession and mutation. On the latter I can offer no opinion or criticism; the former is easy of verification, the densities are about right for the stony casing and the mainly iron core, allowing for the effects of pressure and compression, so that the hypothesis may be accepted as at least a possible one, and it is noteworthy that the limit of the two parts of the earth lie just where the earthquake records indicate a change in composition, unaccompanied by change in state, of the material of which the earth is composed.

There remains the central part of the earth, penetrated by wave paths emerging beyond 120° from the epicentre. In 1906 it was still doubtful whether the so-called second phase at these distances represented the much delayed distortional waves, travelling by a direct path, or was of a different character. In Professor Wiechert's paper, already referred to, the slowing down of the rate of transmission, at depths below a little more than half the radius, was recognized, but the second phase was accepted without question as representing the same phenomenon as at distances of 100° and less, and this has remained the interpetation accepted by the Göttingen school, up to the latest publication which has reached us. In this country the trend of thought has been different; the first noteworthy landmark was the demonstration by Dr. G. W. Walker that what was recorded as the second phase at these great distances synchronized with the time at which waves reflected at, or near, the surface of the earth would reach the place of record,[2] and this seems still the most probable interpretation. Lately Professor H. H. Turner has attacked the same problem and, in the latest reports of the British Association and the Shide Bulletins, has shown, by statistical methods, that the so-called second phase at distances beyond the limit of 120° must be a different phenomenon from the second phase at lesser distances. Meanwhile, by an entirely different path, I had myself arrived at a similar conclusion; the examination of records of instruments of the type generally used in Italy, which give the second phase in an exceptionally clearly marked and conspicuous manner, showed that the so-called second phase at very long distances was of a different type altogether, and a few years ago I was able to examine some of the records of the Galitzin instrument at Eskdalemuir, which gave just the same result. The typical second phase, when well developed, shows a distinct commencement, a well-marked maximum and a less rapid dying out; it is, in fact, patently the record of a single group of waves of one character and

[1] *Göttingen Nachrichten*, 1897, pp. 221–43.
[2] *Modern Seismology*, 1913.

form. At long distances, on the contrary, the commencement is more gradual; there is no well-marked maximum, but two or more succeeding each other, and the record bears the impress of being due to the successive arrival of more than one group of waves, just the appearance, in fact, which would be anticipated from Dr. Walker's interpretation. Taking all this into consideration it is not possible to accept the supposed second phase at distances beyond 120° as being identical in character with the feature which is so well marked at lesser distances, and in these very long distance records nothing can be recognized which may be identified as the arrival of condensational waves travelling by a direct path from the origin; if present they are much reduced in intensity and delayed in arrival. Hence we may conclude that the wave paths which penetrate deeper than the outer limits of a central nucleus, extending to something less than half the radius of the earth from the centre, encounter a material which is devoid of rigidity even against stresses of only a few seconds' duration.

A similar conclusion seems to have been reached by Mr. Harold Jeffreys, if I understand him aright, as the result of a mathematical investigation of the viscosity of the earth,[1] based on tidal deformation and the periodic variation of latitude, so that we have two entirely independent lines of research leading to the same conclusion.

To sum up, we have found that the interior of the earth is divided into three distinct regions, characterized by differences in the physical condition of the material. They are:—

1. An outer crust, of matter which is solid in every sense usually attaching to the word. Its thickness is comparatively insignificant, being little more than half a hundredth of the radius. At its lower limit this passes rapidly into

2. A shell of about half to three-fifths of the radius in depth, consisting of matter to which neither the term solid nor fluid can be applied without introducing a connotation which is contradictory to some of its properties, for while highly rigid as against stresses of short duration, or even of duration measured by years, it is capable of indefinite yielding to stresses of small amount if of secular duration. At its lower limit this passes somewhat rapidly, but more gradually than at the outer limit, into

3. A central nucleus consisting of matter having little or no rigidity, even against stresses of very short duration. Here the material may be described as fluid, whether liquid or gas, without introducing any contradictory connotation.

In composition, as distinct from constitution, the earth appears to consist of two parts; a central portion mainly metallic and principally iron, extending to somewhere between three-quarters and four-fifths of the radius, and an outer envelope composed of stony material.

Geologically, we have a twofold division, into the outer crust composed of material more or less similar, in composition and

[1] Monthly Notices of R.A.S., May, 1917, p. 454.

constitution, to the surface rocks with which we are acquainted, and an inner core which differs in one or both of these characters. Etymologically the word "geology" should apply equally to the study of both these regions, but, for convenience and from the limitation of the individual human mind, it is usually confined to the problems presented by the rocks composing the crust, while those of the deeper regions lie outside its scope.

Such, briefly, are the conclusions which may be drawn from the sciences of terrestrial observation. The statement, I know, is incomplete and imperfect; some at least of the conclusions will doubtless be traversed and regarded as incompatible with the results obtained from other lines of research, but in their main features of the threefold division of physical condition and the twofold division of chemical composition they seem to me so well founded that the burden of proof lies with those who would traverse, rather than with those who are prepared to accept, them.

V.—Notes on Ammonites.

By L. F. Spath, B.Sc., F.G.S.

I.

THE following notes were compiled, for the most part, some years ago, but their publication in the present form suggested itself to the writer on the perusal (during a short "leave" from active service) of a number of recent papers on Ammonites, principally Professor Swinnerton and A. E. Trueman's study of the "Morphology and Development of the Ammonite Septum".[1] The main part of that inquiry is devoted to the development of the septum, illustrated by successive "septal sections", and it is claimed that where sutural development cannot be worked out, "septal sections" will to some extent serve as a substitute. The writer has no intention of discussing the usefulness of "septal sections"; but some of the suggestions put forward, and conclusions arrived at, by the authors, as well as certain opinions, which they adopt from other workers on Ammonites, invite critical examination. Since, in the present paper, other recent work on the morphology and physiology of the Ammonite septum and suture-line, not yet embodied in textbooks, is also included, and since the writer ventures to put forward opinions that differ in many essentials from the views of both textbooks and other authors, it is hoped that the paper may prove of general interest.

The Forward Bulge of the Septum.

Swinnerton and Trueman give interesting contoured plans of the second and of the adult septum of *Dactylioceras commune*, Sowerby sp., and graphs illustrating the average profile of these two septa, and restate that "on the whole the second septum tends to be concave rather than convex forwards" (p. 37), and that "it appears that the [adult] septum as a whole is convex forwards" (p. 32). Professor

[1] Quart. Journ. Geol. Soc., vol. lxxiii, pt. i, pp. 26–58, pls. ii–iv, 1917.

Blake's suggestion is adopted, that this forward convexity of the later septa (so conspicuous only because the average section of an Ammonite happens to pass through the ventral and dorsal lobes) is evidence of pressure from behind the animal; and it is assumed that "in Ammonites the vigour of secretion may have been so great that the gas exerted sufficient pressure upon the soft mantle to make it bulge forward while the septum was being deposited" (p. 33).

The influence of this pressure is referred to in connexion with the modification of the adult suture-line in Dactyloidæ, where among other "ageing" characters of the later suture-lines the authors mention the "more intricate wrinkling of the minor details". They state (p. 39), "This complexity is strongly suggestive of the wrinkling of a collapsing or flaccid bladder, as opposed to the simpler and more turgid outlines of the folioles in earlier septa, and suggests a diminution in the vigour of gas-secretion in the declining period of life." The association of complexity with decline may seem contradictory; for the authors, speaking phylogenetically, say (p. 51) "during retrogression this fringe [of complicated frilling] is gradually lost". This complexity is not so apparent, however, as the other "ageing" characters mentioned, namely the "decrease in the antero-posterior range of the lobes and saddles" or "crumbling down of the apices of the saddles to approximately the same plane", and the "swinging forward of the umbilical portion of the suture-line" (p. 39). Following S. S. Buckman, the authors consider the Dactyliocerates to be "evidently a decadent offshoot of *Cæloceras*", though to the writer neither the decadence of this most flourishing family nor the derivation from the Carixian *pettos*-group, to which the genus *Cæloceras* must be restricted, is evident. They see in them "the phenomena which characterize the first stages in the simplification of the suture-line, a simplification that is carried to such extremes in Cretaceous Ammonites" (p. 40).

Correlation of Suture-line and Whorl-shape.

Attention must be drawn in this connexion to the close relationship that exists between the suture-line and the shape of the whorl. In the Dactyloidæ the tendency is towards loosely coiled, more or less cylindrical whorls, and in the evolution from a cadicone ancestor, through depressed whorls, to the slightly involute shell of the *Dactylioceras* figured by Swinnerton & Trueman, the suture-line would adapt itself to the altered whorl-shape. Zittel[1] stated: "When the whorls are circular one observes ordinarily only a few lobes, and in that case they are of nearly equal dimensions (*Lytoceras*); upon a wide ventral area the external lobe and external saddle acquire considerable dimensions; the flatter the sides are and the thinner the ventral part, the larger the size of the lateral lobes and lateral saddles, and the more numerous the auxiliary lobes." Pfaff[2] mentions that "compressed forms would show the greatest differentiation of their suture-lines in the lateral region and in the

[1] *Handbuch d. Pal.*, vol. i, 2, pp. 332, etc., 1881–5.

[2] "Form u. Bau d. Ammon.-Sept., etc.": Jahresb. Niedersächs. Geol. Ver., vol. iv, pp. 221–2, 1911.

principal lobe; depressed forms on the other hand externally and internally. Again, as during growth the septal surface increases at the relatively quickest rate on the external side, differentiation must begin here".

On examination of the three types of Ammonites chosen by Swinnerton & Trueman, it is found that in *Tragophylloceras Loscombi*[1] with wide lateral areas, the first lateral lobe and first lateral saddle show the greatest differentiation; and in the depressed *Sphæroceras Brongniarti* it is the external saddle. In the Dactyliocerate suture-lines figured by the authors on p. 39 the widest-ventered form (fig. 4) has the external saddle strongly developed, and it has already been remarked that there is a tendency to equalize the size of the saddles on the adoption of a more cylindrical whorl.

It should be pointed out, however, that there are what may be called family peculiarities that modify the suture-elements in certain cases. They are of value in tracing the affinities of homœomorphs, such as the perfectly similar oxycones that appear at so many horizons. The Triassic *Entomoceras denudatum*, Mojsisovics, and the Cretaceous *Garnieria* e.g. had been put into the strictly Lower Liassic genus *Oxynoticeras* by different authors. Although, in the mechanical adjustment to a wider side, either by the spreading-out of the lateral lobes and saddles or by the addition of auxiliary or adventitious elements,[2] similar suture-lines may result in different stocks, yet the modified shells can generally be referred to their ancestral stock by means of some retained family characteristic.

Again, the genera *Macrocephalites*, *Cadoceras*, *Pachyceras*, *Tornquistes*, and *Erymnoceras*, with wide ventral areas, all have a very large external saddle. In *Chamoussetia*, a smooth and keeled descendant of the *Cadoceras* stock, what may be considered the natural adjustment of the suture-line to this type of shell is shown; yet in the later keeled *Quenstedticeras* and *Cardioceras* the suture-line at first still is more or less similar to that of the fat ancestral forms. This may partly be retention of the family character or hastening of the development of the keel; but it may be assumed that ornament and other mechanical expedients for the increase of the solidity of the shell also influence the septal edge. This may account for the changing width of the external saddle in *Macrocephalites* and *Tornquistes* to which R. Douvillé[3] has drawn attention. *Tragophylloceras ibex*, with strong ornament, has a simplified suture-line as compared with the smooth Phyllocerates[4] of

[1] The specimen used by Swinnerton and Trueman for their series of septal sections (fig. 13 on p. 46) shows the small terminal leaflets of the *ibex* group.

[2] Pictet (*Traité de Paléont.*, p. 669) pointed out already in 1854 that the inflated "varieties" of a species often differed from the compressed ones in the number of the accessory lobes, and that modification of the umbilicus produced the same result.

[3] "Etude sur les Cardioceratidés de Dives, etc.": Mém. No. 45, Soc. Géol. France, Pal., i, 19, fasc. 2, p. 14.

[4] Additional work on the various features of the suture-line has demonstrated to the writer the impossibility of basing the separation of genera which other

the ancestral stock. In *Baculites* again, where, theoretically, the suture-elements should be equal, there is a fair amount of variation, caused probably by the differences in cross-section, ornament, and thickness.

It may be added here that certain Lower Aptian developments of the Upper Barremian *Leptoceras* (*trispinosum*-group) show how with the gradual straightening out of the shell the suture-elements become more nearly equal. One such form is e.g. "*Hamites*" *nodosus*, v. Koenen,[1] which, of course, has nothing to do with the Albian genus *Hamites*, just as "*Bochianites*" *undulatus*, v. Koenen,[2] cannot be attached to *Bochianites*, a homœomorphous development of an earlier perisphinctoid Hoplitid. The suture-line of these hoplitid Crioceratids then assumes the aspect of that of the lytoceratid Macroscaphitidæ, and the distinction between these two important families becomes very difficult.

Correlation of Suture-line, Attachment to Shell and Mode of Life.

Another factor has to be considered here. It appears probable that in Ammonites, as in the recent *Nautilus*, the shell-muscle could easily be detached from the shell when the animal moved forward a certain space to form a fresh chamber, and that, as there would have been considerable risk of the shell falling away from its inhabitant, the folded posterior portion of the Ammonite animal with its lobes and saddles afforded the means of holding on, a function performed in *Nautilus* by the strong central siphuncle.[3] When a stock like *Baculites*, in addition to its tendency to equalize the suture-elements of its straight shell, also shows simplification of the suture-line, it may be assumed that it represents an adaptation to a benthonic mode of life which its form alone would indicate. For *Lytoceras* itself, "often as thin as paper and clear as glass, with feeble ornament, i.e. characters that clearly remind one of adaptive forms of nectonic Gastropods of the high seas, *Atlanta*,"[4] and the delicate and smooth shells of Phylloceratidæ and Arcestidæ do not generally show simplification of the suture-line. In the latter, and also in most oxynote shells, so admirably adapted for an actively swimming mode of existence, the need for secure attachment of the animal to its shell was probably greater than in benthonic crawlers.

In those one-sided Ammonites of the Lias, called *Turrilites* by d'Orbigny, which, unlike Buckman[5] I would consider to be such

characters and especially geological occurrence would appear to connect (in this case *Tragophylloceras* and *Rhacophyllites*) on the comparatively insignificant difference in the endings of the external saddle.

[1] "Ammonitiden des Norddeutschen Neocom.": Abh. Preuss. Geol. Landesanstalt, N.F., Heft xxiv, p. 393, pl. xxxv, fig. 13.

[2] Ibid., p. 398, pl. liii, figs. 11, 13, 14.

[3] See E. A. Smith, "Note on the Pearly Nautilus," Journ. Conch., Oct., 1887; and Foord, *Cat. Foss. Ceph. Brit. Mus.* (*Nat. Hist.*), pt. i, pp. xi, xii, 1888.

[4] Diener, "Lebensweise u. Verbreitung d. Ammoniten": N. Jahrb. Miner., etc., ii, pp. 67–89, 1912.

[5] "Vererbungsgesetze und ihre Anwendung auf den Menschen": Darwinist. Schriften, 1, vol. xviii, p. 22 (214), 1893.

adaptations to a benthonic existence, the suture-line is not affected. But in such aberrant types as *Cochloceras*, *Rhabdoceras*, and *Choristoceras*, where the reduction of the septal edges to great simplicity is accompanied by modifications of the coiling, the adaptation to a different mode of life can scarcely be doubted. Professor J. P. Smith[1] calls these "reversionary" types; but if the reduction of the suture-line and uncoiling were reversions to a primitive type, they should be preservative. The writer would also look upon *Œcoptychius Christoli*, Beaudouin, sp., *Popanites patturatensis*, Greppin, sp., and similar forms as aberrant, benthonic types.

"Phylogerontic" Suture-lines. Correlation of Suture-line and Ornament.

With regard to the "reduction" of the suture-line, distinction has to be made between such simplification as is shown in many individual Ammonites, where the last few septa may be simpler and be associated with an (equally sporadical) approximation. This is a growth-phenomenon of the individual. The formation of septa probably ceased when maturity was reached and the character does not become "phylogerontic"; for the stock may continue to elaborate its suture-line. Or, again, in the broad stream of development of a whole family, one branch, under local influences or owing to a tendency to diversity, may modify or simplify its suture-line. It is clear that if whorl-shape and suture-line (and of course also the other characters of the shell) are as closely interconnected as the writer believes, a form like *Hudlestonia* must adapt the suture-line of its probable ancestor *Phlyseogrammoceras* to an oxynote shell, with wide lateral area, according to the general rules mentioned above.

Similar modification is shown in *Staufenia* and *Clydoniceras*.[2] The latter, a local development[3] of the Bathonian *Oppeliæ*, does not so much "reduce" its suture-line as, rather, take on a specialized type that resembles certain "Pseudoceratites", with an increased number of elements, but less frilling. It is to be noted that the families themselves (Ludwiginæ and Oppelidæ) are not affected. In *Proplanulites* and *Pictonia*[4] the reduction is shown in the shortening of the saddles and lobes and the decreased complication

[1] In Zittel-Eastman, *Text-book of Pal.*, 2nd ed., vol. i, p. 673, 1913.

[2] Menzel, *Zeitschr. Deutsch. Geol. Ges.*, vol. liv, p. 90, 1902.

[3] Blake (in *Great Oolite Mollusca*, Mon. Pal. Soc. vol.), from the occurrence of this genus in the southern part only of the Cornbrash outcrop in England, concluded that it was dependent on the presence of the Great Oolite Series below, of whose fauna it was a relic. Compared with the almost universal distribution of the genus *Macrocephalites*, this restriction of *Clydoniceras* is interesting and shows that, like many modern marine organisms, certain Ammonite genera were undoubtedly strictly limited in their horizontal distribution. In aberrant or benthonic types, of course, like the *Oxynoticeras* derivative "*Ægoceras*" *Slatteri*, Wright, or *Nipponites*, the local restriction might be expected, more than in active swimmers.

[4] Tornquist, "Proplanuliten a. d. Westeuropäischen Jura": Zeit. Deutsch. Geol. Ges., vol. xlvi, 1894; also "Die degenerierten Perisphinctiden d. Kimmeridge v. Le Havre": Abh. Schweiz. Pal. Ges., vol. xxiii, 1896.

of their margins. With regard to *Pictoniæ*, Tornquist[1] stated: "We get the impression that they are Ammonites that have resulted from different groups of normal Ammonites, through general degeneration affecting them under local influences during Kimmeridgian times." It must be repeated here that development or loss of strengthening ornament on the shell would affect the suture-line as much as change of whorl-shape. For e.g. in *Pictonia cymadoce* the ornament may be more "reduced" than the suture-line in one specimen, and in another the suture-line more than the ornament.[2]

Adaptation to a Nautiloid, or less exclusively swimming mode of life,[3] might have taken place in *Frechiella*, which is also often one-sided and which shows the modification of its ancestral *Hildoceras* suture-line in its ontogeny. And the oxycones of *Hudlestonia* and *Stanfenia* were better adapted to an actively swimming existence than their Grammoceratan and Ludwigian ancestors. With Renz and J. von Pia[4] the writer would be inclined to favour the theory of adaptation, therefore, even if the special mode of adaptation be not quite clear in some cases, rather than speak of decline of vitality or phylogenetic degeneration.

Wholesale Phyletic "Catagenesis".

This applies, of course, also to the modification of the suture-line in the Cretaceous Pseudoceratites, which, however, is on a different scale, and which has been explained as a phenomenon coincident with the approaching end of the whole race of Ammonites. Walther[5] had stated: "Ammonites, after dominating the seas through three long periods and nearing their end, show in all groups such clear symptoms of abnormal growth, such evident signs of senile degeneration, that their extinction through a kind of senile decay seems to us inevitable." As far as it affected the suture-line, this "degeneration" produced "forms which remind one of Triassic Ceratites and even of certain Palæozoic Goniatites".[6] Indeed, *Neolobites Vibrayanus* (d'Orbigny) and *Metatissotia Ewaldi* (v. Buch) e.g. had been put into the genus *Ceratites* by d'Orbigny and even into *Goniatites* by Pictet. Just as in the modification of the shell, only certain lineages were affected, however, and these differently and at different horizons. But this going back, as it were, along the line followed in the evolution of the group from Goniatites through Ceratites to Ammonites, however incomplete, fitted into the representation of Ammonite phylogeny as a series of cycles "which

[1] Op. cit., p. 42.

[2] Ibid., p. 39.

[3] Diener ("Lebensweise u. Verbreitung d. Ammoniten": N. Jahrb. Miner., etc., ii, p. 69, 1912) says that *Nautilus* lives chiefly crawling, but can swim well and quickly, and has also been found attached to the bottom, which "shows that its present mode of life is little stable yet". Diener, therefore, does not agree with Dollo ("Les Cephalop. adaptés à la vie nect. second. et à la vie benthique tertiaire": Zool. Jb. Spengel. Festschr., Suppl., xv, 1, p. 111, 1912), who ascribes a primarily benthonic mode of life to *Nautilus*, the "type of the ancient Cephalopod with functional, external shell".

[4] N. Jahrb. Miner., etc., ii, p. 169, 1913 (in review of Renz).

[5] *Geschichte der Erde und des Lebens*, 1908, p. 451.

[6] Haug, *Traité de Géologie*, vol. ii, fasc. ii, p. 1166, 1908–11.

is in direct contradiction to a causal explanation of their development"[1], as it conveys the impression of an inborn racial necessity of a predestined character.

The ceratitic suture is one type of line that may recur in the Ammonoid history, just as the same types of ornament appear repeatedly between the Devonian and the Cretaceous, owing to the limited possibilities of variation in each character. Hyatt[2] had considered "the multiplication of the principal inflections in Pseudoceratites of the Cretaceous" to be necessitated "in compensation for the suppression of marginals". The pseudoceratitic suture-line also is not by any means always "reduced", so that its function as a means of attachment of the animal to its shell is not impaired. A form like *Indoceras baluchistanense*, Noetling, with 37 lobes and 38 saddles or 75 elements in its suture-line, recalls the acme of specialization among Triassic Ammonites. According to its author, this youngest of all Ammonite genera, the well-formed specimens of which occur abundantly in beds that pass without break or unconformity into the Eocene, shows no geratologous characters.

Periodic Evolution and Unstable Environment.

It might be suggested that in the evolution of the suture-line "periodicity of elaboration" occurs such as is claimed for other features and as is observed in the Cretaceous Asteroidea by Spencer,[3] and that after a period of "catagenesis" affecting the Pseudoceratites in general, there was renewed elaboration in *Lybicoceras* or *Indoceras*. There can be no doubt, however, that Pseudoceratites represent a number of independent developments of different normal Ammonites, just as the tendency to attain dissimilarity in form, in response to differences of environment, is shown in many different stocks. This ranges from the Hauterivian *Crioceras* to the Maestrichtian *Bostrychoceras* and culminates (morphologically) in the incredible tangle of *Nipponites*; but their relationship is confined to a similar benthonic mode of life. Strong adaptive radiation, such as is generally shown in the young stages of a stock, occurs repeatedly during Cretaceous, as in previous, times. "Changes of structure and diversity of life" are probably "directly related to the physical conditions of habitat", and the "stability of organic forms is in direct ratio to the stability of the conditions of existence".[4] As mutation was so continuous during Cretaceous times, the conditions of existence in so far as they concerned the Ammonites cannot have been stable.

Extinction and Environment. Lime Secretion.

The writer favours the view that the disappearance of Ammonites was not due to inherent phylogenetic relations and inability to

[1] J. v. Pia, N. Jahrb. Miner., etc., i, p. 169, 1914, in review of Mr. Buckman's *Yorkshire Type Ammonites*.

[2] In Zittel-Eastman, *Text-book of Pal.*, vol. i, p. 544, 1900.

[3] "The Evolution of the Cretaceous Asteroidea": Phil. Trans. Roy. Soc. Lond., ser. B, vol. 204, pp. 156–7, 1913.

[4] Joel A. Allen, "The Influence of Physical Conditions in the Genesis of Species": Smithson. Inst. Ann. Rep., 1905, p. 401.

modify, but to physical causes. To quote Diener,[1] "A flourishing family like Lytoceratidæ, which during the whole of the Cretaceous period produced a number of irregular forms and which, itself, persisted later than these irregular forms, cannot by any means be considered degenerate."

One of the most reduced types, with "goniatitic" suture, is *Flickia simplex*, Pervinquière,[2] which is a morphic equivalent of the Triassic *Lecanites*. Whether this is regarded as a local modification of *Neolobites* or an independent benthonic dwarf development, its Cenomanian age is of no significance; for the writer has seen a specimen in the British Museum (Natural History) with a similar entire suture-line (at a diameter of 12 mm.) from the *Caloceras* bed of the Hettangian that looked like a Palæozoic *Pronorites*. The diminutive size of *Flickia*, of course, suggests unfavourable surroundings; but it appears that in the dwarf faunæ of Morade Ebro[3] and other localities the suture-line is little affected.

It is conceivable that thickening of the shell may take place in a series under local influences, i.e. increased lime-secretion, shallowing of the sea, or alteration of the incoming sediment in a more or less confined region. The simplification of the suture-line of *Metoicoceras*[4] (Turonian *Inoceramus* facies) as compared with that of the Cenomanian Acanthocerates may be due to such environmental changes, affecting metabolism generally, and thus the secretion of lime; and this might also apply to the Kimmeridgian *Pictoniæ* already mentioned, where the suture-line may be more reduced than the ornament in one specimen, and the ornament more than the suture in another.

With regard to the simplification in individual Ammonites referred to above, this follows on a continuous elaboration to often great complexity, and is associated occasionally with approximation of the last few septa, which association alone would account for the simplification of the edge. Or, again, they may be thickened, like the last septum of the recent *Nautilus pompilius* or certain Liassic *Nautili*, and thus make up in the enlarging of the adhering surface for what strength was lost in the simplification. No observations seem to have been made on this point, however.

It will be noted that in *Psiloceras* and other Ammonites the last few suture-lines show what Swinnerton and Trueman in *Dactylioceras* call "simpler and more turgid outlines of the folioles", as

[1] Op. cit., 1912, p. 79. Frech, "Neue Cephalopoden a. d. Buchensteiner, Wengener, and Raibler Schichten d. südl. Bakony": Res. Wiss. Erf. Balatonsees. Pal. Anh. z. Teil i d. Bd. i, p. 72 (quoted by Diener), expresses similar views.

[2] The local restriction and numerical insignificance of this "goniatitic" form compared with its normal contemporaries and the flourishing *Scaphites* and *Turrilites* shows the incompleteness of the "cycle".

[3] A. Wurm, "Beitr. Kenntn. Iberisch-Balearischen Triasprovinz": Verh. Naturhist.-mediz. Ver. Heidelberg, vol. xii, 4, 1913. This fauna is even more reduced than that of St. Cassian, which it resembles.

[4] M. Leriche, "Sur la présence du genre *Metoicoceras*, Hyatt, dans la Craie du Nord de la France, etc.": Ann. Soc. Géol. Nord, vol. xxxiv, pp. 120–4, 1905.

opposed to their "ageing" character of more intricate wrinkling, assumed to be due to diminished gas-pressure. *Psiloceras* shows not only complex suture-lines with dependent inner portions at first and simpler ones with ascending auxiliaries at the end, but also often asymmetry of the suture-line, and approximation of the last few septa, and these features will be considered in the following parts of this paper.

(To be continued.)

REVIEWS.

I.—On the Brachiopod Shales of Scania.

Om Skånes Brachiopodskiffer. By Gustav T. Troedsson. Meddelande från Lunds Geologiska Faltklubb, ser. B, Nr. 10, 1918.

THE memoir by Dr. Troedsson on the Brachiopodskiffer of Scania is of importance to students of the Ordovician strata, and must be consulted by anyone who proposes to work at the Ashgillian faunas. These Scanian beds have long been recognized as the general equivalents of the Ashgill Shales of the North of England, which they resemble in respect of lithological characters, fauna, and stratigraphical position.

The memoir is divided into two parts, the first stratigraphical, the second palæontological. In the first part the author gives a historical sketch, which is followed by details of the succession in various localities, and by a comparison of the beds with those of other areas. The second part is concerned with a description of the species.

The fauna consists largely of species which ascend from the *Staurocephalus* beds, but is much poorer in species than are those beds. The author, however, has made a noteworthy addition to the fauna; only five species were known before, whereas he gives a list of forty-six forms.

Although the beds as a whole are equivalent to the Ashgill Shales, it is possible that they contain earlier strata than the lowest part of those shales, for Dr. Troedsson divides them into two sub-zones, the lower (that of *Dalmanites eucentrus*) being distinguished also by the abundance of Ostracods. This is a characteristic feature of a calcareous band with abundant *D. eucentrus* below the Ashgill Shales, which has been bracketed with the underlying *Staurocephalus* beds, and this calcareous band may represent the lowest Brachiopodskiffer, though differing in lithological character. The summit of the Brachiopodskiffer is probably older than the uppermost Ashgill Shales, for the author separates from the former a zone of *Climacograptus scalaris*, which, like the highest Ashgill Shales, is succeeded by the beds of the zone of *Diplograptus acuminatus*. The zone of *C. scalaris* is probably only of local value. *C. normalis* is recorded in England in beds below the Ashgill Shales, and is abundant in the succeeding Valentian rocks, and although it has not yet been found in the shales themselves it must have lived at the time of their formation.

In the palæontological part of the memoir the author gives the distinguishing characters between *Dalmanites eucentrus* and *D. mucronatus*, concerning which there has been so much confusion. The former was described by Angelin from the Brachiopodskiffer of Röstånga, in Scania, and the same author described the latter from the Brachiopodskiffer of Ostrogothia, where it occurs in beds of a higher horizon than the highest beds of that name in Scania, in rocks which contain a Valentian fauna. These two species have been stated to be identical, and it is satisfactory to have a description of their differences. It must be noted, however, that in Scania the two forms occur in the Ordovician Brachiopodskiffer, though it is doubtful whether *D. eucentrus* has ever been discovered in strata of Valentian age.

A new *Dalmanites* (*D. Kiæri*) is described from the Norwegian Brachiopodskiffer, and stated "to be allied to *D. obtusicaudatus*, Salt., from the Upper Caradoc of England". The latter species is really of Lower Ludlow age, and the Norwegian form more closely resembles *D. Robertsi*, described by Dr. Cowper Reed, from the Ashgillian strata of Haverfordwest (GEOL. MAG., Dec. V, Vol. I, p. 106, 1904).

An English summary of the two parts is given in the concluding portion of the memoir, which is illustrated by many plans and sections, and by two plates of fossils and illustrations of others in the text.

J. E. M.

II.—SANTO DOMINGO FOSSILS.

SANTO DOMINGO TYPE SECTIONS AND FOSSILS. By CARLOTTA JOAQUINA MAURY. Bulletins of American Paleontology, 1917, vol. v, No. 29, pt. i, Mollusca, pp. 165–415 (1–251), pls. xxix–lxv (iii–xxxix); No. 30, pt. ii, Stratigraphy, pp. 416–59 (1–43), with sketch-map of expedition, views of country, geological sections, correlation table, and 36 plates of molluscan figures.

THE authoress is already well known to geologists for her memoirs on "Some New Oligocene Shells from Florida" and "The Paleontology of Trinidad". She was fortunate in being selected as a member of a small expedition to the Island of Santo Domingo, in 1916, for the furtherance of geological research, which was carried out under the auspices of the "Sarah Berliner Foundation". In the volume before us comprehensive details are given of the many sections visited on that occasion, from which numerous fossils were obtained, all having been zonally collected and properly localized. These fossils comprised a considerable fauna belonging to several groups of the animal kingdom, although the Mollusca form the larger series and contained over 300 species, many of them being described as new to science. The descriptions of the Mollusca, accompanied by more than 500 illustrations, form the first and largest part of this work, while the second part relates entirely to stratigraphy. The writer refers gratefully to the pioneer work of Colonel Heneken, who nearly seventy years ago surveyed the same

country and made valuable collections of fossils, which he sent to the Geological Society of London, but which have been since transferred to the British Museum. Heneken described the geological features of the region, whilst the molluscan remains were studied by G. B. Sowerby and J. Carrick Moore, and the corals by W. Lonsdale, the combined results forming notable memoirs in the Quarterly Journal of the Geological Society for 1850 and 1853. Both Moore and Sowerby recognized that some of the shells exhibited Pacific affinities, although more often a Miocene facies was apparent with resemblances to those found in the deposits of Bordeaux, Touraine, and Malta, as well as to those of similarly aged beds in the more eastern parts of the United States. At a later date R. J. L. Guppy and W. H. Gabb contributed largely to our knowledge of this subject, and supported the Miocene age for the fossiliferous rocks as first enunciated by Heneken and his colleagues. Like Heneken's collections most of the writer's fossils were obtained from the northern part of the island, in the Yaqui Valley. Among the Tertiary clays and limestones of that district, three well-defined formations, differing in their molluscan faunas, have been determined as the *Sconsia lævigata*, the *Aphera islacolonis*, and the *Orthaulax inornatus*, the last being the oldest. The first named is recognized as belonging to the Burdigalian stage of the Middle Miocene of Europe, the second is included in the Upper Aquitanian or Lower Miocene, and the third is regarded as Rupelian or Upper Oligocene. The Gatun beds of Panama, together with the Alum Bluff and Oak Grove deposits of Florida, are said to be synchronous with the *Sconsia lævigata* formation, whilst the Bowden beds of Jamaica, with a mixed fauna, are scheduled as belonging to both the *Sconsia lævigata* and the *Aphera islacolonis* formations, the latter also including the Chipola River marls of Florida. The *Orthaulax inornatus* formation includes the Tampa silex beds of Florida. Further, it is urged that this fossil fauna of the Yaqui Valley is not only most closely allied to that of the Bowden beds of Jamaica, but exhibits affinities with that characterizing deposits in Cumana, Trinidad, and Martinique.

It will be readily seen from this brief survey of Dr. Maury's book that all the best methods of investigation have been utilized in its preparation. Instead of being satisfied as to the Miocene age of the fossils under which they had hitherto been generally recognized, her employment of the zonal system of collecting, and a careful classification of the numerous molluscan remains obtained, have facilitated the recognition of some important faunal distinctions, and so enabled the writer to divide these Miocene and Oligocene rocks into certain stages which are in agreement with the European standard of stratigraphy.

This is a valuable and an authoritative memoir, and will be greatly welcomed by geologists and palæoconchologists alike, as a history of the Tertiary sequence in this and neighbouring parts of the Western Hemisphere, founded upon molluscan evidence.

R. B. N.

III.—Concretions in the Recent Sediments of the Auckland Harbour, New Zealand. By J. A. Bartrum. Trans. New Zealand Inst., vol. xlix, pp. 425–8, with 1 plate, 1916.

DURING the dredging operations of Auckland Harbour a number of calcareous concretions were brought up by the pumps. These consisted of nodular masses of hard, compact limestone, varying in size from ½ in. up to 6 inches or more in diameter. They enclose recent shells of all kinds, some of which seem to have served as nuclei for the precipitation of the calcium carbonate, and also diatoms and quartz grains. They give no indication of having been derived from any previously consolidated rock, and seem to have been formed contemporaneously with the harbour silt, by precipitation of calcium carbonate from the sea-water. This precipitation was probably occasioned by the decay of organic matter in the epidermis of molluscs, or the hard parts of crabs which form the nuclei of the concretions.

W. H. W.

IV.—The Jurassic Ironstones of the United Kingdom, Economically considered. By F. H. Hatch. Journ. Iron and Steel Inst., vol. xcvii, pp. 71—120.

Average Analyses of British Iron-ores and Ironstones produced in 1917–18. By F. H. Hatch. Published by the Ministry of Munitions. 12 pp. 1918.

AN important part of the work of facilitating the supply of munitions of war lies in the proper development and economical utilization of raw materials. In the case of iron-ores the Ministry was fortunate in securing the services of Dr. Hatch to assist in supervising these matters. Besides the actual mining of the ores it was found that other subjects were also in need of attention, such for example as "blending" of ores of varying composition to produce a standard product, methods of calcining, and economies in transport. All of these are briefly touched on in the first of these memoirs, but the greater part of it is taken up with a description of the actual occurrences and mining of the Jurassic ironstones of the British Isles, with analyses and statistics of production.

The Jurassic iron-ores occur at three principal horizons, namely, in the Lower Lias in Lincolnshire, in the Middle Lias in Cleveland, Leicestershire, and Oxfordshire, and in the Inferior Oolite in Northamptonshire. Expressed in percentages of the Jurassic output the Lower Lias was responsible in 1917 for 22·3 per cent, the Middle Lias for 51 per cent, and the Inferior Oolite for 26·2 per cent. The Upper Lias ore of Raasay amounted only to 65,985 tons or 0·5 per cent of the total. The Corallian ores of Westbury are not now worked.

The most striking recent development is in connexion with the Middle Lias ores of Oxfordshire, which are now being exploited on a very large scale, largely for the supply of furnaces in South Wales. The total output of this county in 1917 was 434,435 tons, with an average iron content of 24 per cent.

The second publication above quoted contains some new and interesting material. It is mainly taken up by a tabulation of analyses of British iron-ores mined in 1917, but the brief introduction of two pages gives in a very condensed form a summary of the statistics of production for 1917. Of 15,028,000 tons mined in that year 89·5 per cent was phosphoric and of low iron-content, the remainder being high-grade hæmatite ore with low phosphorus, obtained almost entirely from Cumberland and Lancashire. The phosphoric ores derived from the Jurassic formation make up 80·6 per cent of the total productione the rest coming from the Coal-measures, with an almost negligibl amount (under 1 per cent) from other sources.

These facts may be summarized as follows:—

	per cent.	tons.
Lias	59·5	8,947,520
Inferior Oolite . .	21·1	3,169,110
Coal-measures . .	8·1	1,194,882
Miscellaneous . .	0·8	129,961
Hæmatite ores . .	10·5	1,586,429
	100·0	15,027,902

Thus it appears that at the present time the Jurassic System is the dominant factor in the iron-ore industry of this country, while the one-time importance of the Carboniferous is rapidly waning. It is, perhaps worth bearing in mind that it was the introduction of the basic Bessemer process that rendered possible the utilization of these low-grade ores, both in Britain and in Lorraine. Without this the course of recent industrial development must have been very different. Fortunately the mining of the Jurassic ores of the Midlands is a very simple matter, being quarrying rather than mining, and the introduction of suitable machinery has done much to stimulate large and economical production in a time of labour shortage.

R. H. R.

V.—An Ancient Buried Forest near Riccarton: its Bearing on the Mode of Formation of the Canterbury Plains. By R. Speight, M.Sc., F.G.S. Trans. New Zealand Inst., vol. xlix, pp. 361–4, with 1 plate, 1916.

THE Canterbury Plains which form the eastern part of the South Island have been built up almost entirely by the alluvial cones brought down by the rivers from the western mountain chains. This deposition of alluvial gravel has been accompanied by a downward movement of the land, and timber is often found in boreholes as much as 450 feet below the surface. The stumps of the trees which formed the forest described in this paper were found in place on a bed of clay, under 12 feet of gravel, at a height of about 50 feet above the sea, in a pit near Riccarton. Some of the trunks were standing, but most of them had been snapped off very

low down. This fact, and the general relations of the clay and gravel in which they were found, suggest that the forest was destroyed by the flooding of the surface with gravel from the migrating cones of rejection, a process which may be seen still in operation in other parts of South Island. The roots were held firmly by the gravel so that the trunks could be snapped off leaving the stumps in place and undisturbed. This occurrence, therefore, is additional evidence in favour of the idea that the Canterbury Plains were formed almost entirely above water, from the gravel of the alluvial fans of rivers, and that the material was not deposited under the sea.

W. H. W.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

November 20, 1918.—G. W. Lamplugh, F.R.S., President, in the Chair.

The President referred with regret to the loss that the Society has sustained by the death of Miss Maude Seymour, on November 6 last, after a very short illness. He alluded to the high value of her services as an Assistant in the Library, and to her energetic assistance in the preparation of the "List of Geological Literature".

The following communication was read:—

"The Geology of the Meldon Valleys, near Okehampton, on the Northern Verge of Dartmoor." By Richard Hansford Worth, M.Inst.C.E., F.G.S.

The area dealt with lies between the London and South-Western main railway line, from a point a litte east of Meldon Viaduct to near Sourton, and the ridge of Dartmoor occupied by Black Tor, High Wilhays, Yes Tor, and West Mill Tor, being the greater part of the valley of the Redaven and a portion of the valley of the West Okement.

The southern extreme of this area is occupied by the Dartmoor Granite, north of which are shales, in which occurs a patch of limestone, and these are intersected by numerous bands of igneous rock.

The shales as a whole, with but slight local deviations, strike north-east and south-west and dip north-westwards, the mean angle of dip being about 50°.

The sedimentary rocks are divisible into:—

1. An alumino-arenaceous series, extending from the granite northwards for a breadth of somewhat over half a mile.
2. A calcareous series, abruptly but conformably succeeding the last.
3. A limestone, which occurs a short distance south of the railway.
4. Radiolarian cherts a little above and a little below the horizon of the limestone.
5. An aluminous bed north of the railway.

Of these, (1) consists of impure grits, which, being well within the aureole surrounding the granite, have developed secondary mica, a little tourmaline, and small well-formed rutiles. In some places, at contacts with granitoid veins, andalusite is also found. (2) Consists mainly of porcellanites with beds of black chert-like rock. The characteristic mineral of the porcellanites is wollastonite, but at contacts with the Meldon Aplite garnet, idocrase, scapolite, axinite, and lepidolite are also developed. (3) Shows little sign of metamorphic action. (4) Are cherts of the character already well known as occurring in the Lower Culm-measures, and described by the late Dr. G. J. Hinde & Mr. Howard Fox. (5) Is a dark-grey rock, almost black, the characteristic mineral of which is chiastolite. All these rocks succeed each other conformably, and there is no evidence of folding or repetition.

In the sedimentary series planes of weakness have developed, the surface traces of which are broadly coincident with the strike, but which frequently lie counter to the dip. These planes have been more or less successfully invaded by at least three series of igneous rocks, the order of which, commencing with the earliest, is as follows:—

1. A felsite with phenocrysts of micropegmatite, and quartz which shows good rhombohedral cleavage.
2. A series, hereafter called the "dark igneous rocks".
3. Granitoid veins, subdivided into—
   (1) The Meldon Aplite and its associates;
   (2) Fine-grained granite of the ordinary Dartmoor type.

The evidence on which this chronology has been based seems fairly clear. The felsite with micropegmatite occurs as inclusions in the "dark igneous rocks". The "dark igneous rocks" occur as inclusions in the Meldon Aplite. The Meldon Aplite occurs as veins in the "dark igneous rocks". No evidence is available as to the relative age of the Meldon Aplite and the granite veins.

A marked feature of the "dark igneous" rocks is that they are locally agglomeratic; as such they have been identified as metamorphosed tuffs. But, on the other hand, every exposure is also in part homogeneous and compact, with clear flow-structure. The inclusions, where present, are always in part fragments of the contact-rocks of the walls of the sills or dykes. Some of the agglomeratic rocks are certainly dykes and not sills, and as such cannot be interbedded tuffs. Every exposure at some place irregularly invades the contact-shales. For these and other reasons their identification as tuffs is dismissed, and it is sought to explain the occurrence of the included fragments by successive injections of the same fissures and the break-up of previously consolidated injected material.

The geography of the Meldon Aplite is described; it occurs in several dykes, the principal of which extends from east of the western wall of Okehampton Park to the old Ice House on Sourton Tor, a distance of nearly 2 miles. There are other minor dykes north and south of this.

The texture of the aplite is microgranitic. The principal minerals are albite, orthoclase, microperthite, quartz, lepidolite, green tourmaline, and topaz. Blue apatite is almost entitled to be classed with these. Fluorspar, montmorillonite, and axinite are accessories. Although, in conformity with other observers, the author has described this rock as an aplite, he uses the term with reservations. The rock is neither more acid than the normal granite, nor does it approach freedom from mica, and he submits that the true description, even if cumbrous, would be lepidolite-soda-granite. The whole of the mica is apparently lepidolite, and of 8·70 per cent, the total of the alkalies, roughly five-eighths are soda and three-eighths potash.

Some veins of true granite occur, always of fine grain: in these andalusite is locally developed. It is noted that topaz and andalusite have never yet been found side by side in any Dartmoor granite or granite vein, but topaz may occur in granite which is in contact with slate in which andalusite is present. In one and the same rock the minerals appear to be mutually exclusive, or, in other words, when the conditions are such that topaz may form andalusite is not to be expected.

II.—Edinburgh Geological Society.

October 16,[1] 1918.—Professor Jehu, President, in the Chair.

"Peat and its Utilisation." An Address by H. M. Cadell, B.Sc., F.R.S.E., Vice-President.

At times such as these, when the Great War had emphasised the need of conserving all natural and scientific resources, the peat question deserved its full share of attention. The high price and scarcity of coal made the prospect of success in the working of peat greater than it had ever been. During recent years peat had been found valuable for producing many other things besides ordinary fuel. By wet or dry distillation, peat products included alcohol suitable for internal combustion engines, ammonia for agricultural fertilisers, acetic acid and acetone for explosives, paraffin for making wax, creosote for preserving timber, tar for coating roads, oil and spirit for burning and power production, as well as gas and coke for heating and smelting. Besides these more or less complex products, the fibrous red peat of the surface of bogs was of great value for moss litter for bedding horses and cattle, and peat dust was useful for packing fragile objects such as eggs and fruit. Cardboard and brown paper, suitable for packing, had been successfully made in America from peat as a substitute for wood pulp, and as timber was now becoming scarce much saving might be made by this use of peat, which was one of the most abundant, but least developed, of our natural resources.

Immense areas of undeveloped peat moss occurred both in Europe and America, the utilisation of which would not only provide good fuel and other valuable things, but would afford useful employment to a large population in many otherwise poor rural districts. In Europe the peat mosses covered over 200,000 square miles, and in

[1] Received November 16, 1918.

Canada half a million, while two-thirds of Newfoundland were under peat. Some of the Scottish peat mosses were as much as 50 feet deep and of great age. Others had, like the Flanders Moss in the Vale of Menteith, been formed since the pre-existing forest had been felled by the Romans. The mosses varied greatly in quality as well as in thickness, and all of them in their natural state contained between 80 and 90 per cent of water, the elimination of which was generally the rock on which industrial peat-producing enterprises had been wrecked. Vast sums had been lost in trying to dry peat artificially either by pressure or by heat, and an evil spirit like the will-o'-the-wisp seemed to haunt the bogs and lure on the adventurer till he was finally swallowed up.

But the light of modern science could show the right path to follow, and as oil shale had only been recognised as one of the precious stones after much loss and hard-bought experience, so would peat moss be made to minister to the needs of man after the wrong roads had been abandoned and the right trail found out. Many new processes have been discovered lately, including Ekenberg's wet carbonising process of heating the wet peat so that it could be afterwards dried by pressure. The briquettes of dried peat were capable of distillation, and as two-thirds of the mass was volatile and about a quarter fixed carbon, it was clear that once the water was successfully eliminated the peat substance was far more valuable than oil shale. The nitrogen in peat was a very important item, and some mosses contained over 2·5 per cent, and the sulphate of ammonia derived from the nitrogen alone might in good mosses be worth twenty-five shillings per ton of dry peat, which was about five times as much as was yielded by oil shale. Alcohol had been made by the fermentation of peat and its wet distillation, and it was claimed that this product could be manufactured for 3*d.* or 4*d.* per gallon. Peat alcohol would be of great value for motors as a substitute for petrol, and if the Government wished to assist the development of this wealth-producing discovery after the War the excise duty might well be greatly reduced, so that the producer would be encouraged to go on and the consumer might obtain the large supply of liquid fuel that was becoming more necessary every day for vehicular traffic and agricultural motor machinery. The development of the peat industry was largely a matter of scientific investigation and technology, and there was in this country an open field and every prospect of final economic success, notwithstanding the failures to achieve it in the past.

III.—Geological Section of the Wellington Philosophical Society, N.Z.

The annual general meeting was held on August 21, 1918.

The annual report, which was read and adopted, stated that since the preceding annual meeting, September, 1917, five ordinary meetings had been held, at which there had been a number of interesting exhibits and eight papers had been read. The titles and authors of the papers were as follows: (September 19, 1917) "The

Geology of the Papakaio District," by G. H. Uttley; "A Comparison of the New Zealand and Western North American Cretaceous and Tertiary Formations," by P. G. Morgan. (October 17, 1917) "Natural Regions in New Zealand," by E. K. Lomas. (May 15, 1918) "The Geomorphology of the Coastal District of South-Western Wellington," by C. A. Cotton. (June 19, 1918) "Notes on the Post-Tertiary History of New Zealand," by J. Henderson. (July 17, 1918) "The Origin of the Amuri Limestone and Flint Beds," by J. Allan Thomson; "Notes on the Geology of Stephen Island," by J. Allan Thomson; "Permo-Carboniferous or Maitai Rocks of the East Coast of the South Island," by P. G. Morgan.

At the meeting a resolution was adopted expressing appreciation of the palæontological work of the late Mr. Henry Suter; and also a resolution expressing appreciation of the palæontological work of the late Dr. E. A. Newell Arber, in particular of his work on the Mesozoic floras of New Zealand.

CORRESPONDENCE.

THE GENESIS OF TUNGSTEN ORES.

SIR,—It is to be regretted that Mr. R. H. Rastall, when compiling his very useful summary of our present knowledge of the genesis, mode of occurrence, and mineral associations of the ores of tungsten, the first part of which appeared in the GEOLOGICAL MAGAZINE for May, 1918, had not before him the results of later researches than those of Dr. Bleeck regarding the ore-deposits of the Tavoy district of Lower Burma, as his results have not been accepted entirely by later workers.

For the past three years a party of the Geological Survey of India has been working in Tavoy, and the district has also had the advantage of the presence of several enthusiastic private geologists. The Geological Survey party has examined most of the lodes which occur, investigated their contents as carefully as possible, and mapped the boundaries of the granite and the sedimentary series into which it is intruded. Our results may be summarized briefly :—

1. Up to the present time not a single specimen of columbite has been found.

2. Tourmaline does not occur in the ore mineral association, and is not a normal constituent of the granite. The occurrence of tourmaline pegmatites is known, but they are not associated with the ore-bearing zones and do not contain either wolfram or cassiterite.

3. Fluor spar is a widely distributed lode mineral, but it is only found in insignificant quantities.

4. Topaz is known to occur in one alluvial cassiterite deposit, and to-day, after three years of detailed field investigation together with petrological and chemical determinations in the laboratory, has only been found in situ once, in conjunction with fluor spar bordering a lode which contains relatively large quantities of pyrite, molybdenite, cassiterite, and very little wolfram. There are over one hundred producing mines in Tavoy district alone, and the lodes examined must amount to many hundreds.

Wolfram and cassiterite are nearly always associated together, though lodes containing one of these minerals, especially wolfram, to the entire exclusion of the other, are known. The mineral association in order of deposition is as follows: molybdenite, wolfram, cassiterite, native bismuth, bismuthinite, chalcopyrite, arsenopyrite, pyrrhotite, galena, and blende. Scheelite also occurs in small quantities. In Mr. Rastall's classification of tungsten occurrences into paragenetic sub-types Burma should be associated with Queensland rather than with Etta Knob and Ivigtut.

In a paper read before the fourth Indian Science Congress at Madras in January, 1916, of which only an incomplete summary has been published (see Journ. As. Soc. Bengal, n.s., vol. xiii, No. 2, pp. ccii–iii, 1917), I have suggested that the place of fluorine and boron may have been taken by sulphur and arsenic in the pneumatolytic stages of ore formation here. I am driven to this conclusion by the universal presence of sulphides, generally in the form of pyrite, in the Tavoyan lodes and the relative absence of minerals containing fluorine and boron.

Some of our lodes are pegmatites. They contain felspar as well as quartz. They have the composition, structure, texture, and other characteristic features of normal pegmatites, but they carry wolfram and cassiterite as well. I have suggested that others in which the pegmatitic origin is not so clear may represent a hydrothermal phase of pegmatite development resulting in the production of quartz with the ore minerals. There are cases here where true wolfram and cassiterite-bearing pegmatites pass in short distances along their strike directions into pure quartz veins with wolfram and tinstone.

I do not deny the part played by pneumatolytic reactions as they are generally understood. I cannot account for the greisens which sometimes border the walls of lodes in granite and also carry valuable quantities of ore minerals by any other theory, but I doubt whether fluorine and boron played much part in the reactions.

It is pleasing to note that Mr. Rastall concludes that there is no real distinction between magmatic segregations and veins in this type of ore-deposit, for if it is correct to regard the pegmatite-aplite group of rocks as differentiation products of granites, it is reasonable to regard their metallic ores as segregations from acid magmas to the same extent.

The wolfram occurrences in other parts of Burma are not identical with those of Tavoy, though this district produces by far the greater proportion of Burma's output. Tourmaline is present in the Mergui lodes and also in those of the Thaton district. Beryl is a common mineral in the lodes of the Yamethin district.

Mr. Rastall has alluded to the widely scattered literature on the subject, and to his bibliography on this district the following published papers may be added: "Economic Geology of Tavoy," by J. Coggin Brown; "The Origin of Wolfram and a Preliminary Investigation as to its persistence at depth in the Tavoy District," by Dr. W. R. Jones. Both these papers are published in a work entitled *Lectures delivered at Tavoy under the auspices of the Mining Advisory Board*, Superintendent Government Printing, Rangoon,

1918. "The Disintegration of Wolfram," a letter published in the *Mining and Scientific Press*, San Francisco, September, 1917, by myself; *The Ore Minerals of the Tavoy District*, by J. Morrow Campbell, published privately, but available from Messrs. Rowe & Co., Rangoon.

As far as I understand their published views, Dr. W. R. Jones supports the pneumatolytic theory of the origin of the deposits, while Mr. J. Morrow Campbell believes that highly siliceous water was the agent which leached tin and tungsten from the magma and at quite moderate temperatures deposited cassiterite, wolfram, and associated minerals in veins.

J. Coggin Brown.
Assistant Superintendent, Geological Survey of India.
Tavoy, Burma.
October 1, 1918.

THE FAUNA AND FLORA OF THE GREAT ICE AGE.

Sir,—The remains of the past fauna and flora have frequently been utilized in supporting the theory of an Ice Age. But little justice has been done to this subject, although it has been maintained by some authorities that the geological history of both animals and plants furnish strong evidence in favour of an Ice Age. In Sir Henry Howorth's series of instructive articles in the Geological Magazine of August, September, and October last he emphasizes some features in the past and present marine fauna of the Baltic which deserve very careful consideration. His remarks about *Yoldia* and its distribution apply with equal force to dozens of other species of marine organisms. The argument that because a species now lives at a certain depth in the Arctic Ocean it must have lived at the same depth during the Ice Age much further south is a fallacy, as Sir Henry Howorth points out. Although some forms of animal and plant life readily adapt themselves to changes of temperature in the course of their migrations most of them require for their existence and welfare a uniform temperature. The conclusions arrived at by Sir Henry Howorth are based on the conditions which obtain almost everywhere near the coasts of Europe at the present day. We may observe Arctic species thriving at considerable depths, while Southern species inhabit the shallow water of the same area. In elucidating the geological history of the Baltic these conclusions, with which I entirely agree, are of the highest importance.

R. F. Scharff.
National Museum, Dublin.
November 23, 1918.

OBITUARY.

JOHN DUER IRVING.

Born August 18, 1874. Died July 20, 1918.

John Duer Irving, the son of Professor R. D. Irving, of the University of Wisconsin, was educated at Columbia University, and

after taking his degree he joined the United States Geological Survey, carrying out work in Dakota and Colorado in conjunction with Whitman Cross and S. F. Emmons. His most important Survey work was a memoir on the Leadville district of Colorado. In 1903 he was appointed professor of geology at the University of Wisconsin and afterwards at Lehigh University. In 1907 he became professor of economic geology at the Sheffield Scientific School at Yale. He was also editor of *Economic Geology* from its commencement in 1905 until his death. When the United States declared war he entered the Army, and soon left for France with the rank of captain. At first engaged in railroad work, he subsequently became instructor in a school of mining and engineering as applied to warfare. Hard work and unremitting attention to duty wore him out, and he succumbed to pneumonia following influenza, to the deep and lasting regret of all who knew him, both in the Army and in the scientific world.

MISCELLANEOUS.

On the Discovery of a Method of arresting the Decomposition of Meteoric Irons, applied successfully to Meteorites in the British Museum (Natural History).

Henry Gadsdon (1861–1918), who died on December 2, aged 57 years, had been for over ten years employed at the Natural History Museum as french-polisher. He was an excellent workman of the best type, one who took pride in maintaining the high quality of his work. It is thanks to his aid that the problem of safeguarding the Meteoric Irons in the National Collections has—so it is hoped—been successfully solved. Every curator who has had such specimens under his care knows well the difficulty of preventing them from rusting. The chief agent in causing the mischief appears to be the unstable protochloride of iron—lawrencite—which immediately breaks down in the presence of damp. This substance is disseminated through certain specimens in extremely thin veins, and, since the change that takes place causes it to swell, such specimens are often found to be split across; further, as a result of the alteration of the lawrencite the nickel-iron alloy which is the principal constituent of the meteorite is attacked, and finally nothing is left of the specimen but a lump of rusty fragments and powder. By keeping the air in the case as dry as possible, the rate of attack may be slackened, but only slackened; the ultimate end is just as sure and inevitable. Varnishing the specimen is more effective, but this process completely spoils the specimen for exhibition purposes. Six years ago, in 1912, as the result of experiments made on pieces of steel exposed to the weather, it was thought that coating the meteorites with a thin, transparent film of shellac by the process of french-polishing might overcome the difficulty without sensibly interfering with the appearance of the specimens, and the Keeper of Minerals decided to have first those specimens which showed considerable signs of rusting treated in this

manner. The work was entrusted to Gadsdon. At first he experienced some difficulty in getting the polish to work properly on the metal, but soon discovered the proper temperature to give satisfactory results, and proved very successful and skilful in treating the specimens. It calls for a careful inspection at a glancing angle to realize that there is anything on a specimen which has been polished, and the harmful rusting has been all but stayed. It is true that some specimens have of necessity been treated more than once, but the cause is no doubt the action that has still gone on in the depths of the cracks within the specimen, and there is evidence that the action is steadily becoming feebler.

In one of his books Wells suggests that in the course of a century or two Meteoric Irons will be represented in museums by lumps of rust; at the Natural History Museum at least, thanks to the method first applied by Gadsdon, it may be that the Meteoric Irons will retain their original form and constitution much longer than that eminent writer foreboded.

G. F. H. S.

Honorary M.A. conferred by Cambridge University on Mr. F. W. Harmer, F.G.S.

At a Congregation in the Senate House at Cambridge on Dec. 7 the Public Orator, Sir J. E. Sandys, delivered the following speech in presenting Mr. Frederic William Harmer, F.G.S., for the titular Degree of Master of Arts *honoris causa*:—

"Abhinc annos quattuor et octoginta natus, adest vir in geologiae scientia penitus exploranda per vitae partem longe maiorem feliciter occupatus, qui patriae toti devotissimus, Angliae Orientalis regionem nobis propinquam ante omnia praetulisse confitetur. Vitae in parte prima, aevi tertii geologici reliquiis diligenter investigandis operam dedit; in secunda, comitatus Norfolcensis in urbe maxima honore municipali summo praeclare functus est; in tertia, ad aevi tertii geologiam, ad amorem suum primum, animi ardore prope iuvenili reversus est. Idem (ne plura commemorem) glacialis aevi et causas primas et eventus ultimos perscrutatus est; ventorum vim in caeli temperie mutanda antiquitus non minus quam recenter multum valuisse luculenter ostendit: ipsas denique causas sollerter investigavit, quae loca illa nobis propinqua, paludosa illa quidem et uliginosa, sed pulchritudine sibi propria exornata, aut olim crearunt aut in amplitudinem maiorem auxerunt.

"Habetis, Academici, exemplar viri, non modo et suo et uxoris suae solo natali, sed etiam patriae toti in unum coniunctae, et rerum naturae studiis devotissimi. Nostis Tulliana illa de loco suo natali verba: 'Omnibus municipibus duas esse censeo patrias, unam naturae, alteram civitatis . . . Hanc meam esse patriam prorsus numquam negabo, dum sit illa maior, haec in ea contineatur.'[1]

"Ut magister in artibus honoris causa nominetur, adduco vobis virum et suo et filiorum suorum nomine, et studiorum suorum propinquitate, nobis coniunctissimum, Fredericum Willelmum Harmer."

[1] *De Legibus*, ii, 2, 5.